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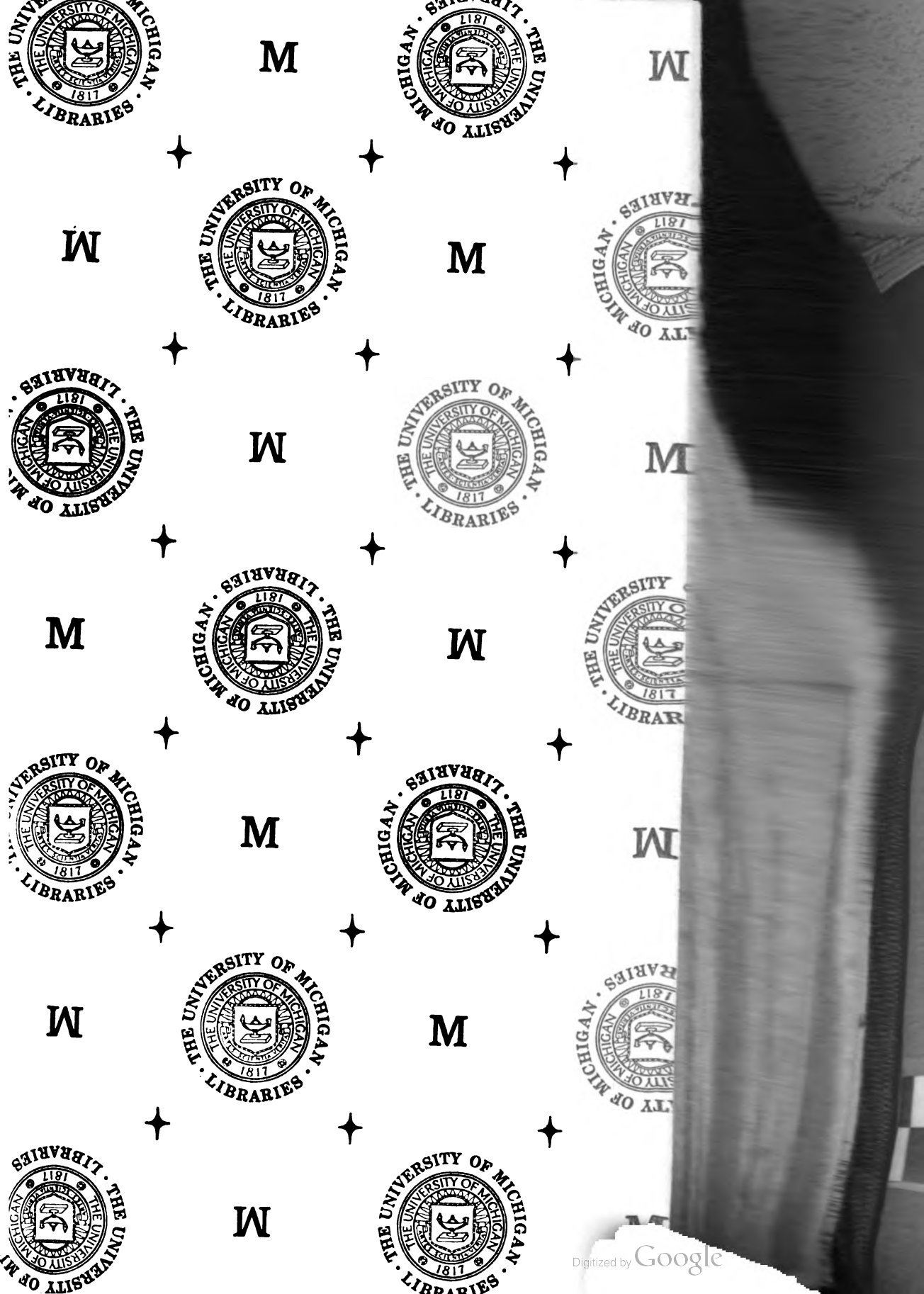
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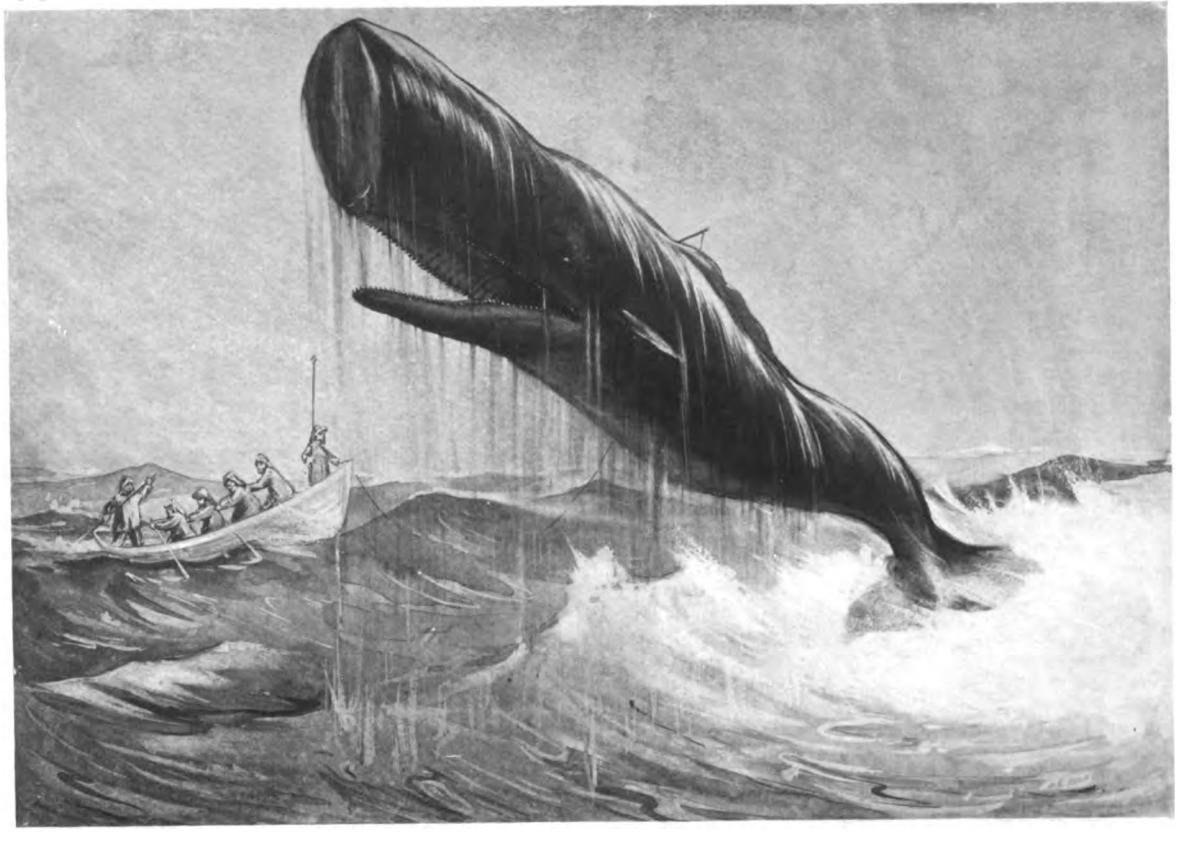

PLATE 1.—*A WHALE "BREACHING."*

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The Evolution

OF

THE SUBMARINE BOAT MINE AND TORPEDO

FROM THE
SIXTEENTH CENTURY
TO THE PRESENT TIME

By
Commodore MURRAY F. SUETER
Royal Navy

SECOND EDITION
with over 200 Graphic Illustrations

GIEVE'S
(Gieve, Matthews and Seagrove, Limited)
THE HARD, PORTSMOUTH

BY SPECIAL APPOINTMENT TO HIS MAJESTY THE KING

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This Book is humbly Dedicated

TO

LIEUT. LOFTUS MANSERGH,

ROYAL NAVY,

SUB-LIEUT. JOHN CHURCHILL,

ROYAL NAVY,

AND

CREW OF "A1" SUBMARINE

(Who gallantly died on duty March 18, 1904)

BY

THE FIRST CAPTAIN OF "A1" SUBMARINE

Toll for the Brave!
  The Brave that are no more!
All sunk beneath the wave,
  Fast by their native shore!

Toll for the Brave!
  Brave Kempenfelt is gone;
His last sea fight is fought;
  His work of glory done.

Weigh the vessel up,
  Once dreaded by our foes!
And mingle with our cup
  The tear that England owes.

COWPER.

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OPINIONS.

Opinion of Lord Charles Beresford, Commander-in-chief, Channel Squadron, 1907 :—

"During the last few years I have watched, with great interest, the enormous progress made in the development of the submarine boat. The more I have studied this mode of warfare the more interested I have become in the subject.

"Commander Sueter has dealt with the subject in a manner which demonstrates an intimate practical knowledge of this means of under-water warfare, and has produced a work of immense value to the modern navy.

"The greatest praise is due to the author for his admirable production."

Opinion of Vice-Admiral Sir Hedworth Lambton, lately in command of Third Cruiser Squadron, Mediterranean :—

"An excellent and most interesting book in which Captain Sueter tells all that is known of the earlier types of submarines, and as much as may be told of the latest developments of these murderous little vessels."

Opinion of Captain Edgar Lees, Royal Navy, Inspecting Captain of Submarine Boats, 1903–1906 :—

"Those interested in submarine boats as they exist to-day, and also in their evolution from the earliest times, cannot do better than read this excellent work by Commander Murray F. Sueter, R.N.

"The writer has had the advantage of commanding later-day submarines, and knows them intimately, and no book yet published either in this country or abroad affords so much accurate and interesting reading as this latest addition by Commander Sueter. Everyone should read it."

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INTRODUCTORY NOTES.

THE whole question of Imperial Defence is one that cannot be regarded in too serious a light by the thinking people of this country. It is essential for us as a great nation to develop the most efficient means at our disposal for the protection of our principal naval and commercial ports; also all adjacent narrow waters of strategic importance must be suitably safeguarded. The means by which this defence is effected should, in its general outline, be known, and have the full confidence of our countrymen. In reading history we cannot help being struck by the enormous importance that has always been attached to the methods adopted for defending our shores from invasion, and we have only to glance at the colossal coast fortifications of this country to see what a large expenditure was once considered necessary for our safety.

The gradual progress of civilisation has not tended to the abolition of armies and navies. Though the greatest triumphs of diplomacy have been accomplished without recourse to the weapons of war, it must always be remembered that these results are directly attributable to the power to strike being *en évidence*.

This could not have been more clearly shown than in the ultimatum delivered to Turkey by Great Britain on May 3, 1906, respecting Turkish encroachments in the Sinai Peninsula. Had not the Mediterranean squadron proceeded at once to Phalerum Bay with every detail completely arranged, should action have been necessary, it is doubtful if Turkey would have so readily complied with our demands.

Adequate naval and military forces are therefore indispensable at all times to ensure that on occasion the just claims of a Government shall be fairly met.

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The requirements of different navies vary. The chief functions of the British Navy are: the protection of, our shores from invasion, our great sea-borne trade, our colonies, our countrymen engaged in commercial enterprise in all parts of the world, our communications for oversea military expeditions or for reinforcing garrisons abroad, and lastly—the most important of all—our warships enable us to work out our destiny as a great nation.

These considerations force us to the conclusion that it is imperative for our Government to provide the most up-to-date units of modern naval science.

The actual use of these weapons must be left to the naval officer, who alone can know intimately the complicated scientific vessels he has to use. No man is capable of appreciating, without actual experience, the relative value of units in problems connected with naval warfare.

Heavy battleships are required as the chief unit for fleet actions, for are we not told almost daily by strategists that our first duty is to attack and annihilate the enemy's fleet, for finding of which, and for the protection of our commerce during hostilities, we require light-draught battleships or armoured cruisers. Scouts are also useful adjuncts to a fleet; but the most important of all units for local defensive purposes are the torpedo flotillas.

Our insular position places us on a different level from other nations as we are the guardians of certain narrow waters, and it depends on our flotillas to hold these narrow waters and endeavour to decrease the fighting efficiency of hostile squadrons before they can unite in force, or prevent detached ships from making raids on our coasts.

A half-hearted attempt was made by the first Peace Conference, inaugurated at the Hague in 1899, for the chief purpose of arriving at some definite agreement between the great nations by which their enormous and ever-increasing armaments might be restricted. General disarmament, however much desired, was known to be out of the question before the sittings began, and it is generally considered that, through lack of previous preparation, the Convention was rather a failure, except that the principles of arbitration were slightly strengthened in regard to minor international issues.

No Powers having questions of a grave nature between them will be bound by arbitration treaties, however lucidly worded. It surely cannot be said that the ethics of arbitration were strengthened by

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the finding of the commissioners on the North Sea incident.* The thinking part of the nation, which at the present time is far larger than hitherto, took a serious interest in the minutes of the Court, and were deeply disappointed with the half-hearted report, which still leaves it open to question if all the evidence available was put before the members of the enquiry.

Of the several proposals considered by the first Peace Conference delegates at the Hague, the following three declarations were ratified, which prohibited for five years:—

1. The use of projectiles dropped from balloons.

2. The use of projectiles which are only intended to spread asphyxiating or noxious fumes.

3. The use of bullets which expand and flatten easily in the human body.

The question of submarine boats was omitted by general consent as it appeared from the outset that there would be no unanimity on the part of the members of the Conference in regard to these weapons.

We take it for granted, then, that as the use of submarines was not even mentioned when the conventions were signed on July 29, 1899, the opportunity was lost, and instead of a deadly weapon being allowed to die out, the representatives of the Powers, figuratively speaking, extended a hand of welcome to this new unit of modern navies. With such a favourable verdict, every nation which aims at naval prestige at once evinced an almost feverish activity in producing these sub-aqueous vessels to strengthen their torpedo flotillas. During the Conference, Captain Mahan, one of the American repre sentatives, is reported to have described the submarine as "inhuman and cruel." Any sacrifice of human life and permanent disability from wounds, etc., is always much to be regretted, and avoided where possible; but an invention which helps with others to deter nations from plunging thoughtlessly and heedlessly into war, or which, when war has once been declared, may tend to shorten hostilities, instead of allowing them to drag on month by month, would seem to be not especially cruel and inhuman.

A speaker at Lord Dunsany's lecture at the Royal United Service

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* Unwarrantable firing on the North Sea fishing-boats by the Russian fleet, 22nd October, 1904.

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Institution a few years ago said: "War . . . must be given her full attributes and painted in her most deadly colours in order that the misery which undoubtedly she brings to the majority of the population may extend over as short a period as possible. Let us make her as deadly as we can in the name of humanity and every good feeling." The great potency of a submarine vessel lies in her invisible approach and the suddenness of her attack; when this is delivered on a war-vessel of the enemy, it may be considered on the same level as sudden fire from a masked battery or from an ambush, which has never been forbidden by the conventions of international law, as secrecy has always been a great aim in war; therefore why should the employment of the submarine boat be questioned in any way. An under-water boat offers the crew some protection, which is totally lacking in a surface torpedo-vessel, and as the accuracy of the Whitehead torpedo depends largely on the method of discharge, a distinct advantage in this respect rests with the submarine. Its existence having now become more generally recognised, an endeavour is made in the following pages to add to the scanty literature on the subject.

In France there are many publications semi-officially recognised in which a mass of fairly authentic details are given; these books have no analogy in this country. Such information as we have is vague, and often so mixed up with fallacious opinions that it is difficult to sift out the facts from the theories.

In consideration of the interest that this subject has for many outside the naval profession, the author thinks it scarcely necessary to offer an apology for making a small effort to unravel a somewhat unwieldy tangle and do his best to place before the readers of this volume a fairly clear and comprehensive narrative, in order to enable them to grasp the various stages in the evolution of a new type of war-vessel and the weapons that will be used in her.

To do this, all irrelevant matter, such as the ordinary diver, his costume, the diving-bell, etc., so frequently introduced at great length in foreign books dealing with this subject, has been omitted, neither is place found for the countless submarine-boat inventions that have never seen the shipbuilder's yard or gone beyond the files of the Patent Office, much less been the basis for any useful experiments.

When discussing the best method of protecting a torpedo-boat against modern gun-fire, Mr. Nordenfelt, in 1886, said: "This led

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me to take up—with a view to make it a practical success—the question of submarine boats; and instead of publishing any accounts of my proposals, I thought it best to build at once such a submarine as could not be suspected of being only an experimental boat, but one really useful in war." What a blessing it would be if more inventors followed this gentleman's example. On an average quite a dozen valueless torpedo inventions, carefully elaborated on paper, arrive at the Admiralty every week. These are mostly from watchmakers in a small way of business—a class evidently possessing a large amount of ingenuity, and who seem to find much leisure for great ideas.

In making a study of our subject we must keep in mind that the modern submarine is not the product of new principles but an application of those already known, and the use, more or less ingenious, of the means which the science of to-day has placed at the disposal of the shipbuilder and engineer. These workers have been able to follow the great strides made in the generating and storage of electrical energy, the development of the Whitehead torpedo and the internal-combustion engine, the advances in metallurgy, etc., and have adapted them to their respective uses in this new construction.

Until the last few years there has been surprisingly small progress—a fact all the more strange, because the utility of these boats, striking at the most vulnerable part of a ship, *i.e.* the portion below the water-line, has so long been recognised. One of the causes of this is that the cost of experimental work is so great that few individuals have had the means with which to start experiments themselves, or to assist the scientific engineers in doing so. The return to the inventor in submarine construction is small. Even if success ensues, this would only be moderate and would compare unfavourably with other fields of enterprise. Also the lessons deduced from the attempts that have been made do not appear to have been systematically recorded, owing no doubt to the lack of intercourse between nations; consequently the pioneers living at different times and in various countries have not profited by the experiences of their forerunners and contemporaries in unravelling the great problems in connection with submarine navigation.

Very few authentic records have been left of these scientific labourers, many of whom spent a large portion of their lives in attempting to overcome the difficulties that confronted them on every side. The records are in several cases almost valueless because

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the writers have had no practical experience in their subject, and nowhere do these errors more glaringly occur than in works on nautical subjects. Indeed, in some of the lectures delivered on early naval history, the student is frequently confronted by quite extraordinary statements from naval historians, who frame and conjure up most improbable strategic movements, whilst their tactical solutions are too far-fetched to ever justify such conclusions, and the tendency to criticise somewhat harshly our great naval commanders of the past is considerably overdone. Such inaccuracies cause much annoyance to those who take an interest in naval history.

The writer in no way wishes to detract from the naval historian of to-day, nor from the two works on submarine boats published during the last few years. Indeed, the latter are most interesting, and one contains much useful historic information, although somewhat scattered; they, however, in each case just lack that practical knowledge which is so essential to treatises on naval subjects. This failing tends rather to mislead and confuse through unthought-out speculations than to offer any real help to the student of submarine navigation.

Lord Selborne,* speaking at Bath in April 1904, said there was a great snare before the modern naval officer, and that was doing things not merely at the call of duty, but because he got his name into the press.

In the opinion of many these words were supposed to be meant to act as a deterrent to those who occasionally contribute articles to the press on technical subjects. This, however, can hardly have been the intention of the First Lord, as a judicious, carefully thought-out paper in a service journal often puts a crooked idea straight.

The result of lack of official encouragement is now beginning to be felt. The United States has produced a great naval historian. In this country up-to-date naval literature is sadly lacking; we hear and read nothing but the well known, threadbare opinions of retired officers on their pet, out-of-date subjects. The Royal United Service Institution presumably exists for the promulgation of up-to-date naval and military thought; but I think, without exaggeration, it may be stated the younger navy is absolutely out of touch with this Institution, a state of affairs which is very much to be regretted, as new

* Then First Lord of the Admiralty.

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ideas and requirements of the modern navy are not being expounded by those who are in the best position to know them. Any up-to-date papers would obviate the contention that the public are without means of ascertaining the broad lines of action that are being determined upon.

Every endeavour has been made to check dates and to give reliable data, but in a work of this description, owing to the great difficulty of obtaining authentic details, a certain number of errors are bound to creep in, and it is found too difficult to enumerate the very many books from which information has been gathered except in the incomplete list placed before the index; but while historical information has been drawn very largely from these and other varied sources too numerous to mention in detail, most of the practical part is derived from the ordinary teachings of the submarine service.

A principal aim, however, in this work is to smooth over a sad memory and remove from a gallant name a small stigma that never should have rested there even for the briefest possible moment. The responsibility for this rests largely with those who, through misconception and hastily formed conclusions, jumped at the first ideas that could in any way account for the lamentable catastrophe which resulted in the loss of all the crew of "A1" submarine. Injudicious questions were asked in the House of Commons; the Admiralty, not being disposed to assist, at that time, in advertising the whole submarine policy of this country, declined to give much information on the subject.

The advisability of witholding the official report on the loss of "A1" I will not presume to discuss in this volume; but it may be stated, without fear of contradiction, that, by doing so, incorrect and unfortunate impressions were produced; some of these were grossly exaggerated through the various channels by which they sifted, until it looked as if a brave officer was being blamed for a disaster for which he was, humanly speaking, in no way responsible.

The British Navy, from the time of Fulton down to the present date, have never wanted submarine boats, but a share in their evolution has been of late forced upon us by other nations; we cannot accept the handicap of not providing ourselves with these vessels, particularly at a time when all navies are striving for high efficiency with every unit.

The preliminary experiments have proved decisive. Relying on

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these results, most maritime Powers believe that the problem, so far as it affects the defence of their coasts, has passed the experimental stage, and that it is advisable to continue upon these lines, and authorise the practical adoption of this new element of war. If in its development it is found to revolutionise naval warfare, then we must be one of the first navies to profit by such teachings and study the advisability of analogous constructions on a greater scale, and lead naval science, rather than follow in the beaten track of other nations with regard to the building of this type of war-vessel. There can be no going back now; the submarine cannot be taken up as a new toy and thrown aside when something more novel turns up. We must make great advances in these vessels in the near future and guarantee good construction in such a form that there must be no unnecessary risk of the lives of the crew.

A complete treatise on submarines would involve a book of several volumes, therefore a compromise between a dreary technical work and a purely reference history has been attempted in which abstruse technicalities have been avoided as much as possible. This, it is hoped, will enable the reader to obtain an insight into the precise value of a weapon that will largely have to be accounted for in future naval wars. If portions of the subject are found only lightly touched upon, it is because the author prefers to say too little rather than too much for fear of touching on confidential matters.

In deciding to write these pages out of respect to his late comrades, the writer begs that the reader will make due allowances for his inexperience in literary work, and trusts they will not be without some interest.

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THE

EVOLUTION OF THE SUBMARINE BOAT, MINE, AND TORPEDO.

CHAPTER I.

NATURE'S SUBMARINE.

BEFORE casting a retrospective glance over the evolution of a submarine boat a few lines might be devoted to the study of the submarine made by Nature out of a mammal.

The order Cetacea * (whales) only differs from the various groups into which the class Mammalia is divided by their adaptation to an entirely aquatic mode of life. They have warm blood, breathe air by means of lungs, bring forth their young alive and actually suckle them.

Their external shape is fish-like, the body being more or less spindle-shaped or fusiform, tapering away towards the tail, which is provided with a pair of lateral expansions called flukes, having very powerful muscles, forming the motive power by which the animal sculls himself through the water.

The forelegs in these mammals have developed into imperfect limbs called flippers, which have very little movement, and are only used for stopping the animal when in motion. During the onward movement these lie close against his side to lessen friction. The hind legs are not developed at all and are concealed in the flesh. Rudimental thigh bones or femora have been found when dressing the skeletons, and are the connecting links which prove the relationship of the whale to other mammals (see Fig. 1).

* Notes taken from the Natural History Museum's pamphlet on Mammals.

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The whale as we know him is quite helpless on shore and passes his whole life entirely in the water. For the purposes of respiration they have to rise frequently to the surface of the water, and therefore Nature has necessitated their tails being expanded horizontally and not vertically like the ordinary fish. This enables them to dive and rise with ease and rapidity.

To make the dive the Greenland whale elevates his flukes 6 to 8 ft. out of the water, contracts his body so that the volume of displacement is suddenly decreased, *i.e.* the weight of the volume of water displaced by a body floating in a fluid is equal to weight of the body.*

If the volume of displacement is suddenly diminished by the contraction of the network system of muscles in the body, the weight of volume of water displaced becomes less; the weight of the body therefore slightly exceeds the weight of displaced water. The whale then sinks to any desired depth and rises again when the contraction is lessened to increase his volume of displacement, until once more perfect equilibrium is restored. The tail is used to help the motion in the vertical or horizontal plane as required.

Speaking generally, the whale is equal in weight to the weight of the volume of water displaced by his body; air is taken in when on the surface sufficient to last the animal for about fifteen minutes, although when wounded they have been known to stay under for fifty minutes. As the air is consumed a slight contraction occurs to compensate for the loss of air, and once more the equilibrium is re-established. The speed of these animals is about four miles an hour, but when frightened they have been known to do eight to ten.† To illustrate the enormous power of the tail, a reference may be made to a whale breaching, the whole length then being clean out of the water, this sometimes takes place when struck in a vital part by the harpoon (Plate 1, *frontispiece*).

The tail of a whale, as we have noticed, lies horizontally; by working the muscles it can be turned nearly vertical, plainly showing what great flexibility it has; this enables many different strokes to be obtained for controlling the speed.

Such power in the muscular extension gives a most effective

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* See Chapter XVI, on Stability.

† Some authorities say 20; but this, I fancy, is an exaggeration.

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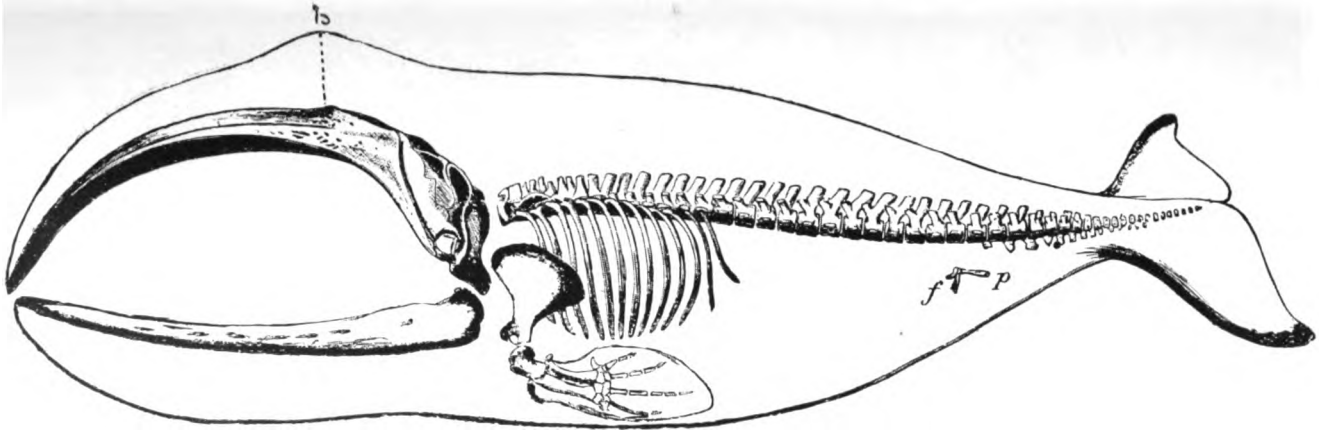

FIG. 1.—*GREENLAND RIGHT-WHALE.*

Skeleton and outline of Animal :—

b.—Position of Nostrils or Blowholes.
p.—Pelvic or Hip-bone.
f.—Rudimentary Femur or Thigh-bone.

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action; and it is thought if a propeller could be designed to travel a certain distance from port to starboard, or *vice versa*, it might be possible to get a better grip of undisturbed water and be more effective. A closer study of quick-moving fish of the Spanish mackerel variety might furnish most valuable information in mastering this complex propeller subject, which at present is so little understood.

Having considered one of Nature's rather clumsy submarines, we pass to one of her ideal models—the salmon (Plate 2). Most of us have seen this specimen, but few know the shape when taking a bird's-eye glance at him (Fig. 2). We then discover that he has a blunt head and a very fine run aft. This gives great speed and quick turning power, the maximum diameter being usually just before the centre. The tail, unlike that of the whale, is vertical and there are four fins, two forward and two aft; these lie close to the side during the forward movement.

Another point to consider is this. Every fisherman knows how difficult it is to land, or partly land, any fish without a gaff or landing-net, irrespective of strength of tackle. This is due to the slime on the body, which serves a useful purpose; and instead of having a hard line where the water ends and the fish begins, we have the water touching a slimy surface that is always renewing itself, and this makes contact with the water as soft as possible.

If we could imitate this slime in practical submarine work by a constant oozing we should obtain very much better speed. Black-lead on the bottom of racing yachts and boats is a well-known treatment for lessening this hard line.

In regard to speed, salmon in the north of Ireland have been observed to swim up a vertical fall of water 12 feet in height. The water in one particular cascade falls into a deep pool, which enables the fish to attain sufficient velocity to swim up the fall. The velocity of the descending water, when it reached the bottom, was estimated at about 28 ft. per sec. The fish went up at about 8 ft. per sec., consequently their velocity through the water was approximately 36 ft. per sec. This gave them a speed of nearly 25 miles per hour, and shows the enormous power of the tail as a propelling agent. Other falls have been watched in British Columbia, where the salmon, in their efforts to reach the upper waters, frequently take large pieces of flesh out of their sides against the sharp rocks. In

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these waters they are very clever in using the rocks as a "take-off," before leaping out of water, in going up the falls; the reason for this is that, unless the salmon is wholly immersed, he cannot get up sufficient velocity, as the propelling power of his tail is lessened when not completely covered, also he requires plenty of space in which to get up speed. Fish in poor condition cannot take these large falls.

In submarine-boat construction it is impossible to copy the delicate material used by Nature, but a certain amount of valuable data can be obtained by a study of the general principles which underlie her teachings.

We deduce from Nature's submarine the following:—

1. If speed be required, a blunt head and a fine run aft would be the best form to adopt.

2. A smooth surface with few excrescences should be aimed at; if these latter cannot be eliminated they should project as little as possible.

3. The means of propulsion will be most efficient if placed in the stern or tail.

4. The system of contraction which makes the weight of the body unequal to the weight of volume of water displaced is one method of submergence.

5. A slimy surface is useful to prevent a hard contact line, and so lessen skin friction.

6. Provision is made to withstand pressure due to the depth of water.

7. An immovable centre of gravity is a distinct feature in all fishes.

8. Buoyancy to enable the surface to be easily reached under normal conditions is essential.

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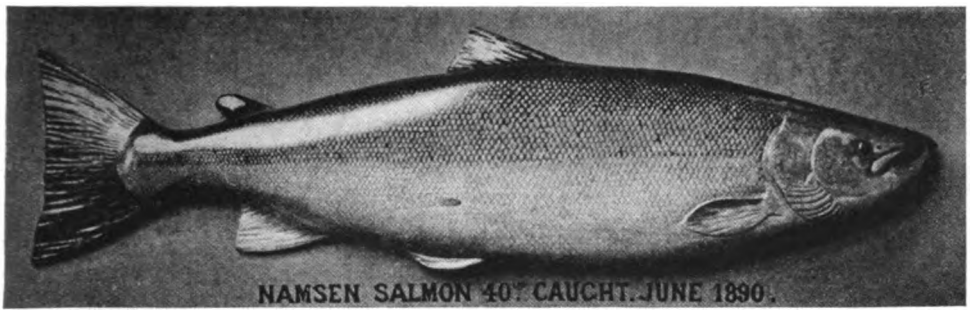
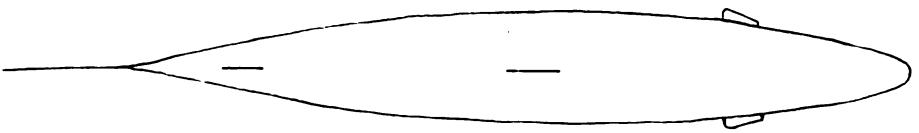
PLATE 2



BY VICE-ADMIRAL SIR W. R. KENNEDY, K.C.B., R.N.

FIG. 2.



OUTLINE OF A SALMON WHEN LOOKING AT IT FROM ABOVE.

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CHAPTER II.

EARLY SUBMARINES.

Bourne, Drebbel, De Son, Symons, Day—1578–1774.

Having briefly considered Nature's submarines, we are now in a position to examine man's efforts in this direction, taking as first principles the data gained from the former.

The essential qualifications for a submarine boat may be summed up in a few words.

1. The vessel should be able to go completely under the surface of the water when stationary or in motion, rapidity of submergence being a *sine qua non*.

2. When in motion under water an even depth-line must be maintained for a prolonged distance.

3. The hull should be capable of withstanding the pressure the water exerts at a moderate depth.

4. The boat should be designed of a sufficient displacement to comfortably contain the means of propulsion, stores, fuel, armament, and provide sufficient space for the crew without undue crowding.

5. Direction on the surface and when submerged should be under perfect control in either horizontal or vertical planes.

6. A fixed centre of gravity is imperative, therefore ballast, stores, machinery, fuel, crew, etc., must remain in their relative positions when in motion under water.

7. Extensive range on the surface and moderate range under water is desirable.

8. When closed down the air supply should be able to meet all reasonable requirements of the crew, either by carrying compressed air in reservoirs or by the provision of some chemical means for absorbing the impurities of the air in the boat. The habitability should ensure the general physical fitness of the crew under most conditions likely to be encountered in real work.

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9. The submarine should be entirely self-contained and be able to act independently from a base or depôt ship.

10. Safety should be ensured under all reasonable conditions of submergence.

In determining the value of the many inventions herein mentioned these fundamental requirements must be borne in mind, also the reader might remember that the small efforts of the early pioneers have been directed towards overcoming the difficulties experienced in satisfying these general conditions. Each important effort has been a stepping-stone towards the solution of under-water navigation, and but for such early attempts it is very doubtful if we should be so far advanced as we are in the present day.

It would seem unfair to dismiss in a cursory fashion these first able workers, and therefore it is purposed to start from the earliest known record of a submarine boat and follow the line of progress right through to the latest scientific achievements, laying stress from time to time on the ingenious ideas which plainly show there was no lack of intellect in working out the details with the crude means at the disposal of the early inventors. Most of these ideas are now of historical interest and well worth investigating.

The first authentic record of an under-water craft dates back to the latter part of the sixteenth century, when William Bourne brought out a book called *Inventions or Devices.** In describing the items of his publication on the first page he considers them as "being very necessary for all Generals and Captains or Leaders of men, as well by sea as land." In article 18 these details are given:

"And also it is possible to make a Ship or Boate that may goe under the water unto the bottome, and so to come up againe at your pleasure, as this, as I haue declared in my Booke called *The Treasure for Trauellers*, in the 4 Booke called *Staticke*, that any thing that sinketh, is heauier than the proportion of so much water, and if it bee lighter than the magnitude of so much water, then it swimmeth or appeareth aboue the water, according unto the proportion of weight, and then this being true, as it is most certaine, then any magnitude or body that is in the water, if that the quantity in bignesse, hauing alwaies but one weight, may bee made bigger or

* Published 1578, London.

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lesser, then it shall swimme when you would, and sinke when you list: and for to make any thing doo so, then in the ioyntes or places that doo make the thing bigger and lesser, must be of leather, and in the inside to haue Skrewes to winde it in and also out againe: and for to have it sinke, they must winde it in to make the thing lesse, and then it sinketh unto the bottome: and to haue it swimme, then to winde the sides out againe, to make the thing bigger, and it will swimme, according unto the body of the thing in the water. And to make a small Ship or Barke or Boate do this, the Barke being made of purpose, let there be good store of Balest in the bottome of hir, and ouer the Balest as lowe as may be, let there be a close Orloppe, such a one, that no water may come into it, and then in like manner at a sufficient height, to haue another close Orlop that no water may come through it, and that being done, then bore both the sides full of holes betweene the two close Orlops: and that being done, then make a thing like the side of the Barke or Ship that may goe unto the side of the Ship, the one for the one side, and the other for the other side, and that must be made so tight and close, that no water may come through it, and that done, then take leather, such a quantitie as is sufficient for to serue your purpose, and that leather must bee nayled close, with such prouision, that no water may soake thorough it, and to be of that largenesse, that the thing may goe close unto the Barke or Ship side when you would, and come in againe, to let sufficient water in, that it shall not be able to swimme. And now this being done, then you must make prouision of Skrewes or other engines, to winde the two things on the insides of the Barke or Ship, that you may winde them in or out at your pleasure and that done, then for the hatch or Skotel, that you must goe in or out, you must haue leather round about it, that you may bring that together as a pursse mouth, and so with a small Skrewe, you may winde it so close together, that being in the bottome of the water, there shall no water come in, and that done, then you must haue one Mast, that must bee of such sufficient bignesse, that it must haue a hole bored thorough the one end unto the other, as a Pompe hath: and that done, then when that you list to anke, then you must sound the deepenesse of the water, and fore see that the water will not rise higher than the top of the Mast, for the hole that goeth thorough the Mast must giue you ayre, as man cannot liue without it: & now when you would sinke, then with

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your Skrewes winde the two sides inwards, and water will come into the holes, and so the Ship or Barke will sinke unto the bottome, and there it may rest at your pleasure: and then when that you would haue it svimme, then with the Skrewes winde out the things on both the sides, and that will thrust the water out againe at the holes, and so it will rise and come up aboue the water, and swimme as it did before, &c." Fig. 1 (2).

Bourne wrote a book a few years after the one mentioned entitled the *Regiment of the Sea.* It opens with a rebuke to those mariners who despise knowledge, and is chiefly interesting because it is the first book in which the method of ascertaining the rate of a ship by means of the log and line is described; also, it explains how the astrolabe * and cross-staff † are to be used, and contains all the astronomical knowledge of that day.

This writer could not have written on these subjects so explicitly unless he had tried or seen actual experiments, and as he claims for his first work the title of *Inventions,* etc., it is therefore reasonable to suppose he was familiar with the details of making a vessel water-tight for going under water. Many writers erroneously give the credit of this invention to Cornelius van Drebbel, a Dutch physician who, in the early part of the seventeenth century, carried out some interesting experiments in the river Thames. As Bourne's book was

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* *Astrolabe* (Gk. ἀστὴρ, "a star"; λαμβάνειν, "to take").—A very ancient instrument for taking observations of the stars, the form of which has varied in different ages. Its principle rested upon the fact that the circles of the celestial concave and those of a small globe may be considered concentric, having the observer's eye in their common centre. The astrolabe used by navigators was simply an annular disc graduated into 360°, and having a moveable diameter carrying vanes; the instrument being suspended by a ring at the point corresponding to the zenith. This, as Sir Jonas Moore says, "is the first and most natural instrument of all others," and, before the invention of the sextant, it was "no contemptible instrument."

† *Cross Staff.*—An old simple instrument for taking altitudes and distances at sea. It consisted of a straight, square, graduated staff and two transoms (each with square socket) sliding on it. The arms of these cross-pieces or vanes were of different lengths: the ten-cross vane belonged to the side of the staff which was graduated towards the eye end up to 10°; the thirty-cross vane belonged to the side where the graduations were from 10° to 30°; the sixty-cross vane to that where they were from 30° to 60°; the ninety-cross vane where they were from 60° to 90°. The graduations were "the natural co-tangents of half-arches, the half-cross being radius." This instrument was also called the *Fore Staff* and *Jacob's Staff.*—Definitions given in *Glossary of Navigation,* Harbord.

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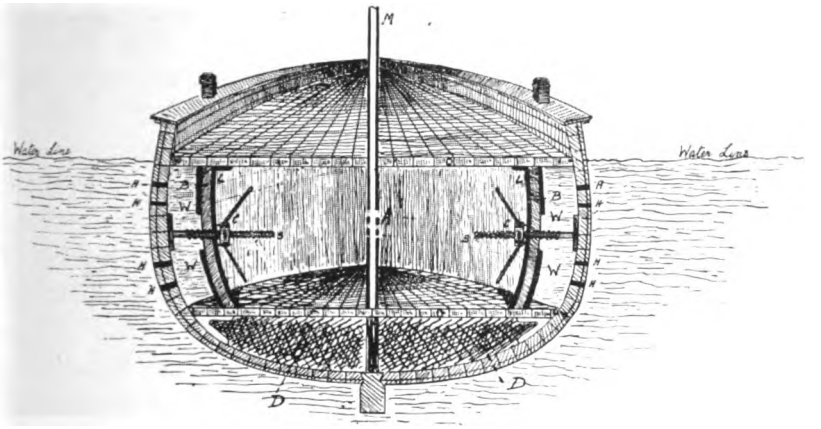

FIG. 3A.—*BOURNE'S SUBMARINE BOAT*, 1578.

A.—Air Holes.
B.—Bulkhead which is screwed in and out.
C.—Capstan for screwing Bulkhead in and out.
D.—Ballast.
H.—Inlet Holes for Water.
L.—Leather.
O.—Orlop.
M.—Hollow Mast for Air Supply.
W.—Space occupied by Water when Craft is submerged
S.—Screws.

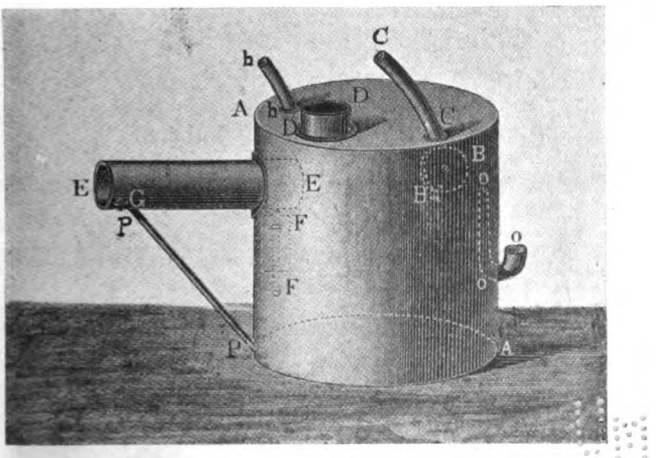

FIG. 3B.—*EARLY DIVING BOAT CONSTRUCTED BY DENIS PAPIN, ON THE LINES OF DREBBEL'S SUBMARINE, FOR PRINCE CHARLES, LANDGRAVE OF HESSE-CASSEL*, 1689.

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written for general information, it is more than probable the Dutchman read the account of how to make the boat water-tight, as he used leather in his experiments for all openings in connection with the water.

We are told by M. Harsdoffer, a personal friend of Van Drebbel, that when the latter was walking on the banks of the Thames he noticed some fishing-boats dragging baskets of fish, and whilst a strain was on the towing-line, the boat was more immersed in water than when it was slack. Following this line of thought to a logical conclusion, Van Drebbel saw no reason to doubt that a boat could be kept partially under water by means of oars or poles, provided she was weighted down with ballast so as to be nearly awash. In 1620 he constructed two small boats of different sizes for use on the Thames. The larger of the two had twelve oars, and the hull was made of wood, strengthened inside with iron bands and covered over with tightly stretched hide soaked in grease in order to keep out the water when submerged. The oars passed through holes in the sides, and leather joints were used to make them water-tight.

The boat could, we are told, keep a few feet under water, and it is recorded that passengers were carried—some authorities even go so far as to say that, as the savant was a personal friend of James I, he persuaded that monarch to overcome his constitutional timidity, and go for a trip under water in the Thames.

This is extremely doubtful, as, even with submarines of the present day, people who are timid would scarcely be keen on facing this somewhat unusual experience. There can be little doubt, however, that James I inspected and watched with great interest a craft rowed with the top of the hull on the surface, or just under occasionally, as, with the crude devices then available, an even depth-line could not have been maintained.

Van Drebbel's boat is credited with a voyage under water from Westminster to Greenwich, but this was no doubt going with the current in an awash condition, the inventor being just able to see where he was steering. This was considered a great feat, as none of the rowers could be seen.

These first experiments have been very much exaggerated, for we find the Honourable Robert Boyle, the chemist, stating that she went under water perfectly, and was rowed about at a depth of twelve or fifteen feet for several hours; this, however, is nonsense. The boat

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could no doubt have been immersed statically, *i.e.* straight up and down. It is practically impossible to make a submarine boat float freely at rest below the surface for any length of time, as the slightest thing will upset the equilibrium. If a little weight is added, the upward pressure, due to the reserve of buoyancy, is overcome and the boat sinks.

If a little weight is ejected, the buoyancy brings the boat to the surface.* Drebbel had no means except oars for assisting to keep the balance. This, it must be admitted, is rather a crude method, and dives of an oscillating nature would be the result. No doubt statical submergences were made, and the tide took the boat in this condition for some distance, but she could not be manœuvred, so we must include her in the category of those submarines that can go right under water, straight up or down, but when required to cover any distance have to keep in the awash condition.

It is also stated, on about as accurate a basis, that Drebbel could purify the air with a fluid which he called the "quintessence of air," a few drops of which, scattered about, gave the operators and the passengers in his boat the faculty of breathing air as fresh and as pure as if they were on the top of a mountain.

The following is taken from a pamphlet on the art of breathing under water, by the Abbé de Hautefeuille.

"The secret of Drebbel was in the apparatus, which consisted of bellows with two valves and two pipes coming on to the surface of the water, one bringing the pure air down and the other conveying the foul air away."

Again, the Honourable Robert Boyle, in a letter to the eldest son of the Earl of Cork, mentions:

"I acquaint your Lordship with a conceit of that deservedly famous Mechanician and Chymist, Cornelius Drebbel, who, amongst other strange things that he performed, is affirmed (by more than a few credible persons) to have contrived, for the late learned King James, a vessel to go under water, of which trial was made in Thames with admired success; the vessel carried twelve rowers besides passengers.

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* See Chapter XVI, on Stability.

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"Having made particular enquiries amongst the relations of Drebbel concerning the grounds on which he conceived it feasible to make men, un-accustomed, to continue for so long under water without suffocation or without inconvenience, I was answered that Drebbel conceived that it is not the whole body of the air, but a certain quintessence or spirituous part of it that makes it fit for respiration, the remaining grosser body or carcase of the air is unable to cherish the vital flame residing in the heart. Beside the mechanical contrivance for expelling air, he had a chymicall liquor which he accounted the chief secret of his submarine navigation. For when from time to time he perceived that the finer and purer part of the air was consumed or even clogged by the respiration and steames of those that went in his ship, he would, by unstopping a vessel full of this liquor, speedily restore to the troubled air such a proportion of vitall parts as would make it againe for a good while fit for respiration, whether by dissipating or precipitating the grosser exhalations or by some other intelligible way." *

Drebbel, no doubt, was just as bent on keeping his invention secret as the submarine designers of to-day, and encouraged rumours to the effect that he could remove the impurities from the vitiated air. It is undoubtedly a fact that he conceived some contrivance, as stated by the Abbé, so that his passengers should suffer no inconvenience whilst closed down for running on the surface or under the water.

John Wilkins, the brother-in-law of Cromwell, in his book *Mathematic Magick* published in 1648, refers to the successful experiments of Drebbel, and improves on them on paper, in a clever essay.

He carefully studies the pros and cons in chapter v, from which we take the following interesting remarks on the difficulties that would have to be faced in the submarine boat which he calls the "Ark":—

"The letting of anything out of the 'Ark' without the letting in of the water; the difficulties of steering when we have neither winds nor tides to help us nor the sight of the heaven for direction; the progressive motion of the vessel, to be accomplished by oars, the

* Page 364 *et seq.*, Hon. Rob. Boyle's *Experiments on Air*, Oxford, 1660.

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ends of which are, like the fins of fish, 'to contract and dilate'; its ascent and descent, and so on.

"He seems inclined to think that long use and custom (which in other things doth produce such strange, incredible effects) will produce a race of men to whom it will not, perhaps, be so necessary 'to have the air for breathing so pure and defecated as is required for breathing.'

"For it is not easy to recite 'the many advantages of the "Ark" to the Nation.' First and foremost ''tis private.' A man may go to any part of the world invisibly without being discovered or 'prevented' in his journey. Man will be safe from the violence of tempests 'which never move the Sea more than five or six Paces deep'; they are safe from Pirates and Robbers, from Ice and great Frosts which are such deadly foes to us in our 'passeges towards the Poles.' One is also free from the uncertainty of the tides. It may be of a very great Advantage against a Navy of Enemies, who by these means may be 'undermined in the Water and blown up.' So, too, it may be of great use for the relief of a place beseiged by water, 'to convey unto them invisible Supplies,' and also for the capture of a place that is accessible by water. 'It may be of unspeakable benefit for Submarine Experiments and Discoveries.' We can compare the swiftness of ascent of bladders and corks with the rapidity of descent of stones or lead. We may explore subterranean passages and caverns. We may study the nature of fish; and we may catch them by alluring them with lights or by shooting them with guns, 'put out of the Ship by means of Bags.' And fish are important, for they give the occupants of the 'Ark' the oil they require for 'Dressing Meat by Lamps.' Fresh water for the occupants may be got from the pure springs at the bottom of the ocean. 'But above all, the discovery of submarine treasures is more especially considerable, not only in regard of what hath been drowned by Wrecks, but the several precious things that grow there, as Pearl, Coral, Mines.' Several Colonies of people may inhabit these vessels, 'having their Children borne and bred up without the knowledge of Land, who could not chuse but be amazed with strange Conceits upon the discovery of this Upper World.'"

Careful search has been made for a drawing of Drebbel's boat, but without success. An account, with diagram of a similar vessel, built

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to the order of Charles, Landgrave of Hesse-Cassel, is given in a magazine * of a later period. This prince, being told of the extraordinary convenience of the famous diving-ship constructed by Drebbel, commanded one of the like kind to be built. In Fig. 3 (b), AA is a wooden tub of an elliptical oval shape, 6 ft. in height, as many in greater diameter, and 3 ft. in the lesser; BB is the Hessian rotatory sucker and forcer which attracts the external air down the pipe CC; DD is a hole which serves as a door; EE is a great cylindrical copper vessel, 6 ft. long and 1¼ ft. in diameter. The whole aperture is within the tub AA, and is closed, as is also the hole DD, in the most exact manner, with plates fitted for the purpose and screwed very tight. PP is a prop to support the cylinder arm, FF being a pump by which the men shut up in the tub may introduce air into the cylinder EE to repel water from the hole G, through which the man included in the cylinder will be able to destroy the enemy's ships.

The pressure on the sides is prevented by the round form of the tub and the weights put in the bottom to sink the tub and resist the pressure in that part; and as for the upper part, the pressure of the incumbent water is not considerable, because it is not necessary for the tub to descend very deep.

Fresh air will be attracted through the pipe CC, and the superfluous air expelled through the pipe *bb*. The U-curved barometer OO opens at both ends; the whole lower part may be made of iron or wood and shows the depression of the ship very exactly. It may be further depressed by letting in the external water by a cock. But to prevent the ship being quite sunk by letting in too much water, two men ought always to be trying to depress it by the help of oars, and when they find it can be done without much stress the cock is immediately to be shut, by which the ship will, for any space of time, be kept lighter than water and yet may, by means of the oars, be depressed more and more at discretion. The oars are to come through lateral holes, which are most exactly closed by leather bound about them, as was also practised in Drebbel's ship. When we think fit to emerge or raise the ship the thing is easily effected, partly by the help of oars and partly by expelling the water by a pump contrived for that purpose.

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* *Gentleman's Magazine.*

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As to the difficulty of breathing in such a ship, Drebbel mentions that he had provided a certain quintessence of air, one drop of which emitted would render the vitiated air again fit for respiration; but Dr. Papin imagines this rather a thing to be wished than a reality. This account bears out the Abbé's ideas of the method used by Drebbel for obtaining air; the two pipes (*b* and C) are clearly shown, and no doubt were fitted in Drebbel's boat. Van Drebbel died in 1634 and left no authentic record of his experiments.

The poet-laureate, Ben Jonson,* in the *Staple of News*, Scene I, Act iii, referred to Van Drebbel's submarine boat thus †:—

"*Thomas*— They write here one Cornelius' son
Hath made the Hollanders an invisible eel
To swim the Haven at Dunkirk and sink all
The shipping there.
Pennyboy—But how is't done?
Cymbal— I'll show you, sir.
It's an automa, runs under water
With a smug nose, and has a nimble tail
Made like an auger, with which tail she wriggles
Betwixt the costs of a ship and sinks it straight.
Pennyboy—A most brave device
To murder their flat bottoms!"

De Son—1653.

A few years after Van Drebbel's attempts with under-water boats, a strange vessel was constructed at Rotterdam in 1653, from the designs of a Frenchman named De Son, and two illustrations of this boat are given (Plates 3 and 4). The text ‡ above the original drawings runs as follows:—

"The true & perfect forme of the Strange Ship built at Rotterdam A. 1653, the inuentor of it, doeth undertake in one day to destroy a hondered Ships, can goe from Rotterdam to London and back againe in one day, & in 6 Weeks to goe to the East Indiens, and to run as

* Born 1574, died 1637.
† Taken from *Submarine Navigation*, by A. H. Burgoyne.
‡ Text taken from *La Navigation Sous-marine*.

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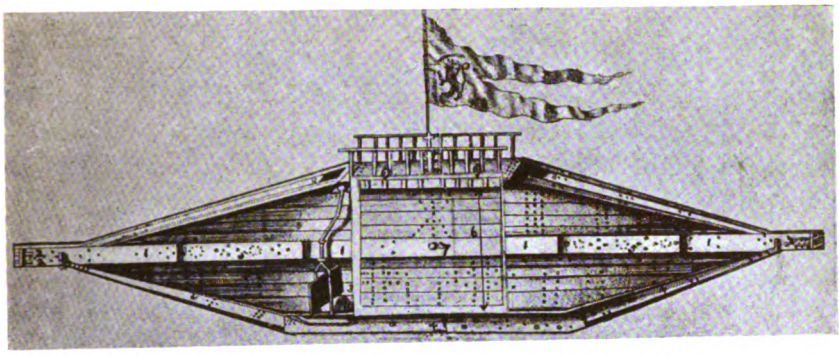

PLATE 3.—*SUBMARINE BOAT CONSTRUCTED AT ROTTERDAM IN* 1653 *BY DE SON.*

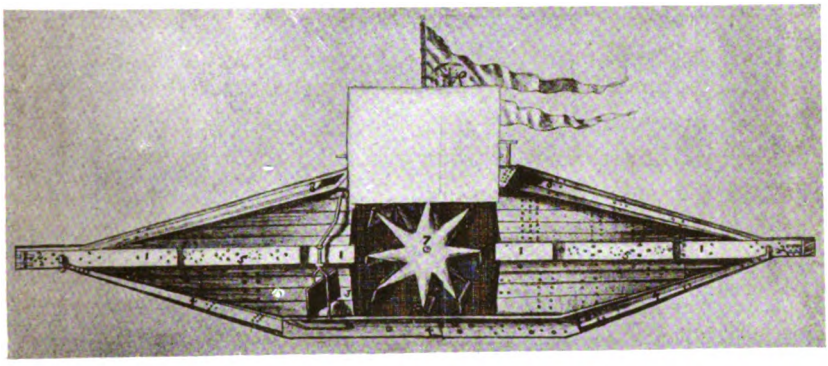

PLATE 4.—*DE SON'S SUBMARINE SHOWING INTERNAL PADDLE WHEEL.*

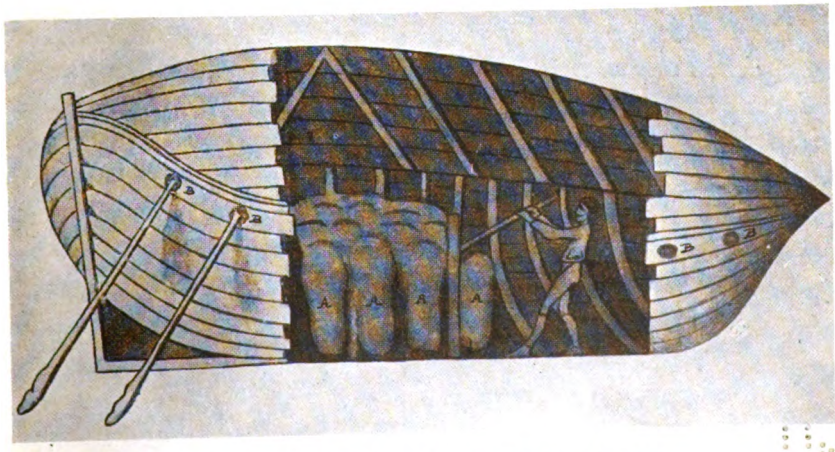

PLATE 5.—*SYMON'S SUBMARINE BOAT*, 1747.

A.—Leather Bottles for carrying Water Ballast.
B.—Oar Apertures made watertight with Leather.

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Swift as a bird can flye no fire, nor Storme, or Bullets, can hinder her, unlesse it please God, Although the Ships meane to bee safe in their hauens, it is in vaine, for shee shall come to them in any place, it is impossible for her to bee taken, unlesse by treacherie, and then can not bee governed by any but himselfe, the drawings shew 1. The middle beame, 2. the two ends with Iron barrs, wherein the Strength of the Ship lieth on both ends alike, 3. the rudder of ye Ship, 4. the kiele, 5. Iron boults with scrites, 6. the depth to the middle beame, 7. the wheele that goeth round by which it hath its motion, 8. the Shuttles where they goe in, 9. the Gallery where they walk."

She was 72 feet in length,
12 feet maximum in height,
8 feet in breadth, tapering towards points at each end.

The hull was made of wood strengthened by iron girders, and down the whole length was a solid beam of wood heavily tipped with iron at the extreme ends. The boat when ballasted down was under water, except the midship part, which had a sort of hand-rail. Here we see a great attempt to use water as a protection for the major length of the boat when used for offensive purposes; and the claim of the inventor, that no damage could be done by heavy cannon shot, was fairly sound.

At both the fore and after ends of the boat a cabin was fitted the air in which remained good for three hours or so. In the centre of the boat we notice a large wheel very much resembling the paddle-wheel of to-day (Plate 4). This could be rotated by a clock-work mechanism, and it was stated this apparatus could run for eight hours when once wound up. Sails were not required; and the inventor claimed that his design would give great speed; also, by the iron tipping of the pointed bow and stern of his boat, he could sink the biggest English ship afloat by crushing into her bottom under water. In October 1653 this boat was nearing completion, and so confident was the inventor of his success that, in conversation with those who came to see the marvellous invention, he said he wanted no trial, but only a river trip. A launching day was fixed; invitations were issued; notabilities came from all Holland. But just before the eventful day De Son announced that his boat could not be got ready in time for lack of certain materials.

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This is not unknown in the present day, for we find that a submarine-boat inventor, giving a display at the Northampton Institute, in December 1904, to a crowded gathering of students, found one model, when it got to the bottom, stayed there, and the other refused to submerge. The disappointed students were told that a small connection had apparently gone wrong!

De Son's boat was subsequently launched, and on a trial of the machinery being made, the revolving paddle-wheel, that did so well in air, would not move in water. Why? We have a very good illustration of this in the modern locomotive torpedo.* If the compressed air is turned fully on to the engine when the torpedo is out of the water, the revolutions of the propellers are about 2000 per minute. If the torpedo is then fired into the water the number of revolutions drops to some four or five hundred per minute, the decrease being due to the water acting as a resisting medium. Thus, in the case of De Son's submarine, probably, the paddle-wheel could be made by his mechanism to rotate some few hundred revolutions per minute in air, but once in water the machinery was not powerful enough to drive the paddle-wheel at any speed. This was apparently the only reason for De Son's failure, for his principles were distinctly sound, and he is undoubtedly the inventor of the first mechanically propelled semi-submarine boat that could take the offensive beneath the surface. The boat was launched, but failed, due to want of power, and De Son finished by exhibiting her for a trifle to any casual passer-by. References have been made to this boat in many foreign publications; and even in official documents, as in a report made to the French Ministry n 1832 by M. Vileroi, attention is called to the submarine boat constructed by a French engineer in Holland during the middle of the seventeenth century.

Symons' Submarine—1747.

Many years went by without any great addition to the science of submarine navigation; although some diving-bells were constructed and several patents taken out for submarine appliances, nothing very practical was done. In the *Gentleman's Magazine* of 1747 there is an article on an under-water boat, built by a man named

* Chapter XXII.

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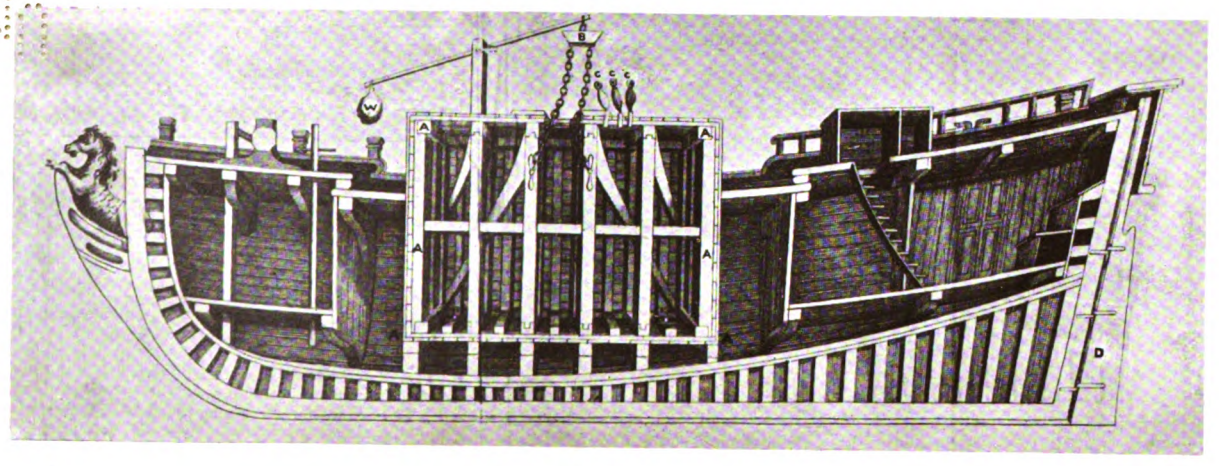

PLATE 6.—*DAY'S SUBMARINE*, 1773.

A, *A*.—Air Chamber.
B.—Cover for Air Chamber Opening.
W.—Counterpoise for Cover B.
C, *C*, *C*.—Coloured Buoys for Signalling Purposes.
D.—Vertical Rudder.

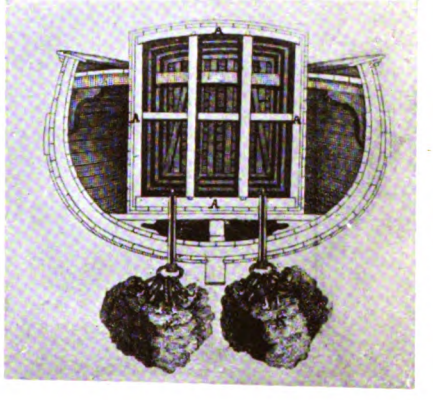

PLATE 7.—*DAY'S METHOD OF SUSPENDING STONE BALLAST*.

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Symons, who experimented with his invention on the Thames. This took the form of an ordinary wooden boat of the period, with a dome-shape cover over the usual open part, completely closing it in, and strengthened with wooden ribs, the whole being covered with greased leather to render the seams water-tight (Plate 5).

To sink her in the water, a number of leather bottles were placed with their openings in the bottom of the boat. The pressure of the water due to the height of water at that depth caused them to fill if the necks were untied, and when full up the boat was just awash. She was propelled by eight oars, four working on each side. To rise again to the surface, the bottles were squeezed out by hand and then tied round the necks to prevent the water coming in again. This is exactly the same principle as that employed in all the latest submarines, the squeezing out being done by compressed air and, instead of the string used to tie up the necks of the bottles, kingston valves are fitted and tanks substituted for bottles. The illustration is taken from the *Graphic*.

Day's Submarine—1773.

~~Some few years later~~ we read ~~of~~ an ingenious ship's carpenter named ~~Day~~ experimenting with various models, which resulted in a small boat being converted into a diving-machine. This contrivance ~~was~~ submerged in the Broads near Yarmouth. The inventor's success in sinking to a depth of 30 ft. and rising without accident, caused him such satisfaction that he induced others to join in the construction of a second boat; a sum of £340 was placed at his disposal, with which he bought a sloop of 50 tons and fitted her out for more extended experiments ~~(Plate 6)~~.

The air-chamber was constructed amidships. Day was the pioneer of utilising detachable ballast; large stones with ring-bolts fixed in with lead were hung outside the vessel and could be slipped from inside (Plate 7). These were to be let go should a sudden rise to the surface appear desirable. One successful submergence was made in Plymouth Sound, but a deeper and more exposed part of the harbour was chosen for the second dip, which was attempted on June 20, 1774. At first the boat had too much buoyancy, and, under the directions of the daring inventor, additional stones were added, after he had made all tight inside, until she sank; downward

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momentum was given by these extra stones, and the boat went to the bottom in 22 fathoms. We are told Mr. Day's patron watched from a barge the spot whence the boat vanished with a pensiveness that seemed to forebode to his mind an evil omen.

A system of signals by releasing coloured floats was arranged for, but none appeared. The hour for the boat to reappear passed, and it became evident some mishap had occurred to this intrepid man. No doubt the pressure due to the head of 22 fathoms of water was too much for the wooden structure, which soon collapsed.

Lord Sandwich* was at Plymouth at this time, and the resources of the dockyard and H.M.S. "Orpheus" (frigate), anchored by, were placed at the disposal of those who were interested in getting the boat up, but to no purpose; and Mr. Day was numbered amongst those who have given their life in attempting to conquer the laws of Nature. A London physician, hearing of the accident, hastened to Plymouth, being urged by a great belief in his own professional capabilities, as he thought Day was unlikely to be touched by fishes; being inside the air-chamber of the boat, his blood also would remain in good condition for a considerable time in such a cool place. Merely the animal functions would have been suspended, and he would be able to restore life if he could only raise the boat before decomposition set in. With this idea uppermost, he applied to the Admiralty for further assistance in raising the craft, but the First Lord replied that, once all chance of saving the man's life had passed by, the Admiralty begged to be excused from taking any further steps in the matter. Not discouraged by this, the enthusiastic doctor undertook private sweeping operations, and the wreck was grappled in 22 fathoms of water, 150 fathoms from the shore.

Cross bearings:

St. Nicholas Sd. due south;

Fire Stone Bay N 1° W.

These attempts, owing to the bad weather, all failed, and the physician had to abandon his efforts and return to London. This account is taken from a book published shortly afterwards by the doctor to explain the reason why he attempted to raise the boat.†

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* Lord Sandwich was then First Lord of the Admiralty.

† Notes taken from Dr. Falcke's book on his unsuccessful effort to raise Day's submarine, London, 1775.

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CHAPTER III.

BUSHNELL'S SUBMARINE—1776.

WITHOUT entering largely into the historical events that preceded the American War of Independence, we notice in various publications that the Seven Years' War had been undertaken by the British chiefly for the protection of her great American colonies; and as it was found necessary to keep a large number of troops in America, the home Government considered the colonies should contribute their share in meeting these expenses. Therefore in 1767 extra taxes were levied on such articles as tea, etc., entering the ports of America. This caused the gravest dissatisfaction, as the colonists, whilst admitting their liability to be taxed, contended that the duty should be imposed by their own colonial Parliament, and refused to pay. In addition to the question of taxes, many statesmen in this country advocated a policy whereby the manufacture of goods should not be permitted in the American colonies, and that all manufactured articles should be sent out from the old country in exchange for raw material. The colonies naturally resented this policy of restriction, which limited their expansion by preventing all chance of commercial dealings with other nations.

These and other circumstances did not lessen the friction then springing up between the two countries; the tension continued for some years, during which time resistance took more and more vigorous measures, the colonists even going so far as to throw whole shiploads of tea into Boston harbour rather than pay the duty. Open rupture finally followed these acts. The first skirmish took place in 1775, and a year later the colonies united and issued their Declaration of Independence. As a result of this the British Navy was ordered to blockade the Atlantic ports of the rebellious colonies. The inconvenience and misery caused by this rigid measure forced native inventors to turn their attention to any weapons that could be used

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effectually against their enemies either on shore or afloat. As one of the latter was the most successful attempt to solve the problem of submarine navigation since its inception, it would not be out of place to offer some passing attention to the inventor.

David Bushnell was born at Leybrook, now Westbrook, U.S.A., and educated at Yale College,* graduating in 1775. During residence at this establishment Bushnell attempted to solve some of the problems appertaining to sub-surface navigation; and, becoming deeply interested in these researches, soon saw the possibility of a successful issue should experiments be prosecuted in this direction. About this time the war was just commencing with England, and bringing the usual devasting results in its path. Bushnell fully realised what these privations meant for a large number of people, he also felt with much bitterness the operations then being undertaken by his country's enemies in her home waters.

With such antagonistic feelings, it was only a short step for this clever man to throw his whole energy into some means of devising a weapon which would act most effectively against the blockading ships then operating on the coast.

A gunpowder charge, exploded in contact with the most vulnerable part—the bottom of a ship—he considered to be the most effective means of breaking up the blockade.

In order to fix this charge, some ready means of placing it under the surface at any depth required was necessary, and also a device to fire the explosive, at the same time providing a sufficient time-interval to allow the operator to make good his escape before the actual explosion took place. An under-water boat was therefore designed to embody these requirements as far as engineering science of that day permitted it. The external shape bore a slight resemblance to two tortoise-shells placed hollow to hollow against each other, and forming an egg-shaped structure, a form which gave good stability and great strength (Plate 8).

The body of the vessel, to use the inventor's own description, was made exceedingly strong, and to strengthen it as much as possible a firm piece of wood was framed parallel to the conjugate diameter to prevent the sides from yielding to the great pressure of the incumbent

* Became Yale University, 1887.

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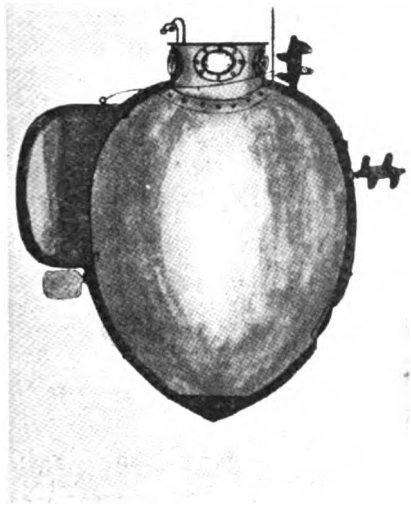

PLATE 8.—*BUSHNELL'S SUBMARINE*, 1776.

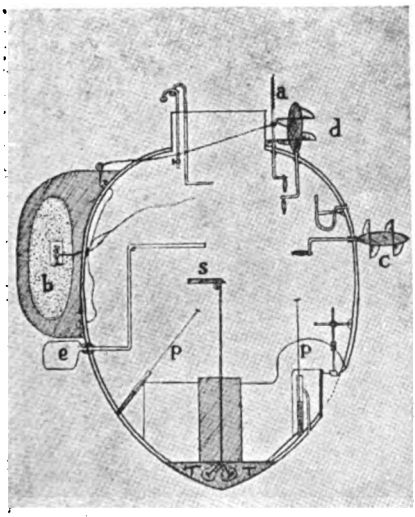

FIG. 4.—*BUSHNELL'S SUBMARINE SHOWING INTERIOR.*

a.—Screw to which Magazine was attached.
b.—Magazine
c.—Screw-shaped Oar for going ahead or astern.
d.—Screw-shaped Oar for forcing the Boat under water.
e.—Rudder.
p.—Pumps.
T.—Water Ballast Tanks.
s.—Seat for Operator.

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water in a deep immersion. This piece of wood also formed a seat for the operator (Fig. 5).

An aperture at the bottom, with its valve, was designed to admit water for the purpose of descending, and two brass forcing-pumps were provided for ejecting the water when necessary to ascend. A compass directed the course, a water-gauge or barometer determined the descent, and a ventilator with an opening within supplied fresh air when on the surface. A brass crown or cover, resembling a top-hat with its crown and brim, was constructed on the upper part of the hull to form the conning-tower, the entrance to which was just large enough for a man to get through; this was fitted with a hinged water-tight cover opening sideways. Three holes were provided in this tower, with covers ground with emery to fit in tight; these were large enough to put one's hand through. Several small scuttles were also fitted for observation purposes and the admission of light to the interior.

The vessel, with all the various fittings, weights, etc., on board, was very low in the water. When the operator desired to descend he placed his foot upon the top of a brass valve and depressed it, by which water entered through a large aperture. If he admitted too much he ejected as much as was necessary to obtain an equilibrium by the use of forcing-pumps.

At the lower end, opposite the entrance, there were 700 lbs. of lead ballast, a portion of which, namely, 200 lbs., could be slipped by means of a cord from inside the boat, and this acted as a safety weight enabling the boat to rapidly rise in any emergency.

The air contained inside the craft was enough to last the single occupant for about thirty minutes.

With the water-tank full, the boat had the top of the conning-tower level with the surface of the water. In this condition, Bushnell relates, the skilful operator could "row upwards or downwards or continue at any depth with an oar placed near the top of the vessel, formed upon the principle of the screw"; also an oar, formed upon the principle of the screw, was fixed in the fore-part of the vessel; its axis entered the vessel, and being turned one way rowed the vessel forward, and being turned the other way rowed the vessel backward. It was made to be turned by the hand or foot as required.

This system would control a boat under water if very skilfully handled, but in practice a man could not drive the boat forward,

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steer and screw the vessel under at the same time with any degree of success, so all versions of this boat running miles under water are simply efforts of imagination. Bushnell, no doubt, submerged his boat into an awash position retaining a little buoyancy, and, looking through the conning-tower, worked her in the direction required on the surface. To submerge entirely, a little more water ballast was taken in to destroy all buoyancy. We shall find in a later chapter, when studying the principle of equality of weight and submerged displacement, that it is not a practical success, even with fairly modern appliances, as the "Goubet," * experimented with in 1885 *et seq.*, used this principle, and was not very successful in keeping an accurate depth-line. The screw is supposed to have been invented some years later by Sauvage, but the principle was known in the seventeenth century. Hooke wrote on the subject in 1680; it would seem unlikely that the ingenious American was not in touch with what many scientific men were attempting in this direction in the eighteenth century. Several writers question the genuineness of Bushnell's screw-shaped oars, and say these have been added subsequently to give additional importance to the invention. There can be no reason for doubting Bushnell's own writings or his system of working the boat, which allowed the operator to use one arm to steer with and a hand or foot for the vertical and horizontal screw-shaped oar as required; the latter was placed at the fore-end of the boat, instead of at the stern, as is now usually the custom.

The tiller of the rudder was made sufficiently long to reach under the operator's arm; a vertical motion could be obtained by taking in water ballast to destroy all buoyancy; the boat could then, by controlling the admission and ejection arrangements, be worked up and down at the will of the occupant.

In a recent volume on *Submarine Boats* the author, one regrets to say, falls into the category of those mentioned in the preface to this volume when drawing attention to many writers' lack of personal experience in their subject, and in a somewhat scanty description of Bushnell's boat says:

"The weird and absolutely incomprehensible pumps and tubes fixed in the hull also lend it an air of mystery which is suspicious." If this writer put Bushnell's submarine the right way up, the various

* Chapter X.

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operating levers, etc., would be more explicit than when looked at upside-down! *

On the outer shell of the boat was carried, immediately above the rudder, a detachable magazine. The idea was for the operator to place his craft alongside an enemy's ship, showing as little as possible. More water ballast was then taken in, and, with the aid of the vertical screw, she was forced some small distance under water, and an attempt made to get under the bottom for the purpose of forcing the wooden screw, carried at the foreside of the conning-tower, into the hull of the ship attacked. The magazine, containing 150 lbs. of powder, was then detached from the boat, and the tide acting on the case, which was buoyant and attached to the screw driven into the hull, made it lie alongside the ship. A clockwork mechanism could be set for firing this charge at a sufficient interval of time to enable the boat to get clear away; this was arranged to be safe for thirty minutes after the operator had made the magazine dangerous. The mechanism revolving released a trigger, which allowed a gun-lock hammer to fall on a percussion-cap and so fire the large quantity of explosive. In the interior of the boat a tube was fitted to act as a water-gauge and allowed the water to enter, which showed the level of the water outside; a little piece of cork covered with some composition of phosphorus gave a glimmer of light to show the height of the water.

A small compass was also provided to allow of a fairly correct course being maintained, phosphorus being again used to illuminate the principal points, otherwise at night the boat was in total darkness.

Bushnell did not work his invention himself, but first depended on his brother, until the latter fell ill, and then he asked General Parsons for three volunteers from the army. These were promptly forthcoming; but why the General did not recommend sailors is a puzzle, as they would have been far more likely to obtain some results, and no doubt a few volunteers would have come forward from the seafaring class of the southern States. The first experiments in Long Island Sound were distinctly promising, but were interrupted by the English ships, which necessitated the boat being transported overland from New Rochelle to the Hudson River

* *Submarine Navigation*, page 13, Plates iv, v.

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until all was clear again; then she was brought back to New York.

The English fleet, supporting their army as much as possible, anchored off Plateau Island. In 1776 a suitable night was chosen for making an attack on the blockading ships with Bushnell's submarine, manned by a sergeant of the name of Ezra Lee. The vessel was taken in tow by two rowing-boats off the New York shore and towed towards the English fleet. On arriving within a few miles the submarine was set adrift in a strong tide, setting towards the ships. Sergeant Lee soon found himself swept outside the ships; but after the tide slacked a couple of hours' work on the screw-shaped oar brought the boat close to H.M.S. "Eagle," a 64-gun frigate, commanded by Captain Duncan and flying the flag of Lord Howe, then lying off Governor's Island in New York harbour. The ship showed up clearly, and the brave man with his imperfect weapons tried to attach the magazine, but failed to get the screw into the bottom of the ship —a fact probably due to the hull being sheathed with copper. Two different parts of the hull were tried, but without success. As daylight was near, no further attempt could be made, and the sergeant gave up his daring enterprise as he had 4 miles to go before reaching safety; but the tide being now favourable, he made good progress. When near Governor's Island some of the soldiers discovered the submarine by her conning-tower showing above water, put off in a boat and gave chase. Lee, considering capture was certain, slipped the explosive magazine, as this retarded his progress in the swell, and the soldiers, thinking it was a ruse, abandoned the pursuit. The magazine subsequently exploded. The boat reached safety, and the operator was helped out, none the worse for his exciting experience.

When New York was evacuated Bushnell's boat was taken to a river farther north, and is supposed to have made an unsuccessful attack on another English ship, but, owing to a good look-out being kept, the attempt failed, and the towing-boat was damaged by shot, although the submarine escaped without injury. A third attempt was made in the Hudson River, above New York, against another English ship, but this also proved unsuccessful.

All Bushnell's attempts failed, and the cause was undoubtedly the inexperience of his operators. Their training was difficult; but the inventor tried his best to make them efficient by always keeping

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a tow-line on the boat until they appeared thoroughly to understand her, and gave them as much personal teaching as the limited time permitted. Lack of money prevented Bushnell making any further attempts, so he turned his attention to developing various experiments which had clearly proved that gunpowder could be exploded under water.

Bushnell for his services received a commission in the army, and on the conclusion of hostilities went to France for some time, but afterwards returned to his own country and took up his residence at Georgia. Here he studied medicine and amassed a considerable fortune under an assumed name, but not until his will was read was his identity as the inventor of the infernal machine made known.

Bushnell will always be remembered as the first inventor of a sub-aqueous vessel that actually went into action. If one of his three attempts had been successful the evolution of these boats would have advanced considerably.

The following points stand to his credit. Recognising:—

1. That a very strong form of hull was necessary to withstand the pressure due to the depth of immersion.

2. That gunpowder could be made to explode under water. Consequently Bushnell became the inventor of what is now known as submarine mining.*

3. That the bottom of a ship is the most vulnerable part to attack with an explosive charge.

4. That a conning-tower placed directly above the centre of gravity of his boat helped considerably towards her stability; also this tower allowed vision when the submarine was trimmed to the awash condition.

In the war waged by this country in 1812 against the United States over the "rights of neutrals," a similar boat to that constructed by Bushnell was apparently built by an inhabitant of Norwich, United States, for the purpose of attacking the English ships, for we find that an under-water craft was used against H.M.S. "Ramillies," then commanded by Captain Thomas Hardy.†

In the biography of this officer the following interesting passage

* Bushnell's Mines, Chapter XXI.

† Nelson's Hardy, afterwards Captain Sir T. Hardy.

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occurs: "In July 1813, whilst the 'Ramillies' was lying at anchor off New London, the deck sentinel sang out 'Boat ahoy!' on seeing an object rise to the surface close astern of the ship. It immediately disappeared. An alarm-gun was fired, hands called to quarters, the cable cut, and the ship got under way.

"Once more the mysterious stranger rose. Before the guns could be trained on it, it dived again, and fastened itself on the keel of the British ship. There it remained for half an hour, during which time a man within it succeeded in drilling a hole through the copper of the 'Ramillies'; but the screw with which he was attaching the explosive broke, so that the attempt failed. The inventor of this diving-boat by means of paddles was said to be able to propel it at the rate of three miles an hour under water, and to ascend and descend at pleasure."

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CHAPTER IV.

FULTON'S SUBMARINE.

THE "NAUTILUS"—1801.

THE disturbed state of America in the early seventies of the eighteenth century led to Bushnell's submarine boat being brought into being and then recognised as a distinctive weapon for war purposes.

The work in connection with this type of vessel initiated by Bushnell was further advanced by an ingenious American engineer named Robert Fulton, who was born in 1765 at Little Britain, now called Fulton, State of Pennsylvania, U.S.A. This great inventor's early career was somewhat hampered through lack of means. At first he obtained a precarious livelihood as a jeweller's apprentice, then as a landscape and portrait painter in Philadelphia. These efforts brought in sufficient remuneration to enable him to come to England in 1794 to further study his art. The first two years of residence in this country were spent in Devonshire, during which period the budding inventor devoted a considerable portion of his time to the study and application of mechanics, and became associated with the Duke of Bridgewater in various canal schemes for improving inland navigation. Young Fulton's inventive capabilities were soon generally recognised as being of a high order, and he subsequently patented many devices in flax-spinning, double inclined planes for canals, mills for sawing marble, rope-twisting machines, etc. In 1797 a countryman persuaded the American to take up his residence in France, where he soon came into prominence by offering the French Government various ideas on canals, dams, etc., and we hear of him as the first inventor of the panorama, brought out towards the end of 1797. Fulton, in addition to his inventive capabilities, was a deep thinker on the problem of universal disarmament; he considered the war systems of the Old World were the cause of the misery of

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the greater portion of its inhabitants. This, he thought, was chiefly brought about by oppression of the weaker nations by the more powerful, by excessive direct and indirect taxation, by compulsory service, the latter being necessary to keep up naval and military forces to enable the aggressive Governments of that day to carry out their grasping policies. Fully recognising the importance of sea-power, he feared that as the United States increased in prosperity she would have to provide a navy for her protection, which would be inimical to her republican institutions and destructive of her happiness.

Fearing this retrograde step, Fulton wrote: "I devoted my whole attention to find out means of destroying such engines of oppression by some methods which would destroy such systems."

Out of these ideals grew Fulton's explosive inventions for use in maritime warfare. Indirectly, the submarine boat was further developed as a means of operating more secretly with explosives in actual war. In glancing at the military situation at this time we find the French ports being blockaded by the English ships. The details of these operations are too well known to need any comment in a volume of this nature.

Fulton considered the occupation of all Governments should be largely devoted to education, diffusion of knowledge, and the encouragement of Free Trade; also he desired that all nations should acknowledge the "freedom of the seas"; from this would naturally follow a free exchange of natural advantages, relief from trouble and expense of foreign negotiations backed up by large armaments, etc.

His first experiment with a device whereby the freedom of the seas might be obtained was carried out in the Seine in the early part of 1797. This was a machine designed to impart to carcasses of gunpowder a progressive motion under water. These the inventor at first styled submarine bombs. They were not altogether a success, but convinced Fulton his ideas might be developed could he obtain sufficient money to prosecute the invention. With this in view the following letter was drafted and sent officially to the Directory, which I take the liberty of quoting in full as it is of much historical interest now that this method of warfare is attracting universal attention, and it also shows what a formidable weapon the submarine was thought to be a hundred years ago.

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"13 December, 1797.

"CITIZEN DIRECTOR,*—Having taken great interest in all that would diminish the power of the English Fleet, I have planned the construction of a mechanical engine, in which I have the greatest confidence, for the annihilation of this Navy. Some practice is, however, necessary to perfect the apparatus. The grandeur of the project has excited in me an ardour to share in a demonstration of this engine. To this end, in order to save you all trouble, I have formed a Company which will undertake the expense and carry out the work on the following terms:—

"1. The French Government undertakes to pay the Company of the 'Nautilus' 4000 francs a gun for every English ship above 40 guns which the inventor destroys, and 2000 francs a gun for every ship below 40 guns, these sums to be paid within 6 months of the destruction of each ship.

"2. All the English merchant ships or war vessels captured to be the property of the Company without any hindrance on the part of the Government agents to prove that they are English property.

"3. The Government accords to the Company of the 'Nautilus' the monopoly of this invention for all the French ports, that is, if the Government does not wish to construct similar boats. The Government in this case is at liberty to construct as many 'Nautiluses' as it pleases, provided that 10,000 francs are paid for each 'Nautilus' used by the Government.

"4. Being a citizen of the United States, I desire it to be stipulated that this invention or a similar one will not be used by the French Government against the United States, or, at least, the Americans must use them first against France before this stipulation is annulled.

"5. If peace is concluded with England within three months of this day the Government will pay the Company all the sums spent on experiments; this to be paid within three months of the signing of peace.

"6. As in the case of fire-ships or other contrivances for the destruction of ships which are considered to be against the Laws of War, the people who take part in these enterprises are hung or put to death, the Directory, to prevent this, will accord to the Company

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* Many French books, as *La Navigation Sous-marine*, *Les Bateaux Sous-marins*, etc., refer to this correspondence between Fulton and the Directory.

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of the 'Nautilus' a commission specifying that every person made prisoner in a 'Nautilus,' or one of the Company's expeditions, is to be treated as a prisoner of war, and any hurt done to them is to be met by similar reprisals on English prisoners.

"Citizens, as I firmly trust this engine will give liberty of the sea, it is important to experiment as soon as possible so that, if she succeeds, the Terror will be scattered before the invasion of England, and the boat can be employed in assisting this invasion.

"In submitting these proposals to your deliberations, and awaiting your orders, I remain, with all possible respects,

"ROBERT FULTON.

"556 Rue de Bac."

The many propositions were accepted in general, except the sums of recompense, which were considerably cut down. The clause too about peace was not consented to as the creation of a submarine boat was supposed to inspire a great fear, which might bring about a cessation of hostilities in a very short time. The commission clause, however, was the real stumbling-block. The Minister of Marine refused to grant a commission to the crew, and with this opinion most of the naval officers of that day agreed; they considered such a method of waging war unworthy of the French honour.

The reprisal clause was also thought to be superfluous, as in England at that time there were three times as many French prisoners as English prisoners in France.

A Commission of naval officers was appointed to examine the proposals of the American, and reported favourably upon them. In spite of this the Minister of Marine gave little encouragement to these schemes. The inventor then made a model of a submarine boat from which explosives could be used, and submitted it to the Directory in order to further his designs, with the double assurance that he would compel the English to raise the blockade, and not only that, but with this new weapon he would force into the naval ports of Great Britain, blockade the Thames, and cut off the commerce of London. The plans were again rejected; and Fulton then laid them before the Dutch Government, who also gave him no hope that his ideas would be taken up. Three years later we find the inventor approaching Bonaparte, then First Consul, who was somewhat drawn to the clever American, and appointed three eminent men to examine into the details of the drawings and make a report to him. He also

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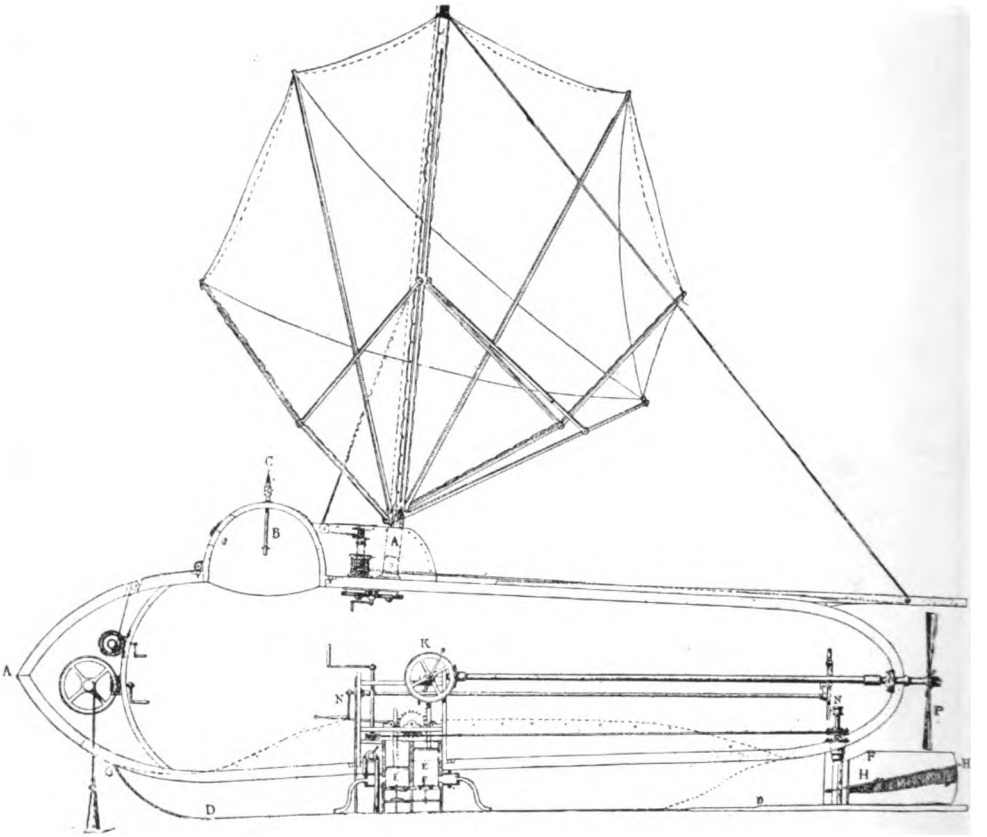

FIG. 5.—*THE "NAUTILUS" OF FULTON.*

A.—Mast.
B. Conning Tower.
C.—Spike for putting into the Bottom of a Hostile Ship.
D, *D*.—Keel.
E, *E*. Kingston Valves.
F.—Vertical Rudder.
G.—Anchor.
H, *H*. Inclined Plane Diving Rudders.
K.—Hand Wheel for rotating Propeller P.
N, *N*.—Gearing for working Vertical Rudder.

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licensed a grant of 10,000 francs of the public money to enable Fulton to proceed with the construction of his first boat.

She was laid down in the winter of 1800 and completed by May 1801, being launched under the name of the "Nautilus," having the following dimensions, 21 ft. 4 in. in length, 7 ft. in diameter (Fig. 5).

Her hull was an imperfect ellipsoid in form, as shown in the diagram, and was made of copper with iron frames supporting the plating. The boat also had a heavy detachable keel running fore and aft which could be slipped on emergency. Tanks were fitted into which water ballast was allowed to enter before submerging.

This boat was one of the type which take water ballast into tanks so as to decrease buoyancy until the weight of the volume of water displaced is equal to the weight of the boat. As we have already mentioned, in this method it is most difficult to obtain an adjustment of ballast, constant attention to pumps is necessary, and only an erratic depth-line can be obtained.

To assist the control in the vertical plane two inclined planes HH were fitted, their arc of travel being 30° above and below the horizontal. A double cylinder force-pump was used to remove the water ballast as required.

The conning-tower was hemispherical in shape and built up on the fore-end of the boat, being provided with the usual look-out scuttles of thick glass, etc. The anchor gear was arranged to be let go from inside the boat without opening the conning-tower hatch. The hull of the boat was constructed to withstand the pressure exerted at a depth of 25 feet of water.

The offensive power of this vessel consisted of an explosive magazine. The "Nautilus" was supposed to pass under a ship's bottom and drive a nail into her hull; this had a hole in it for the purpose of securing a light tow-line fastened to the copper magazine that held the powder. A trigger of a gun-lock released a hammer when subjected to any blow; this fell on a percussion-cap and so fired the charge.

The boat was provided with a mast and sail for surface work, which allowed her to manœuvre at a speed of 2 to 3 knots ~~per hour~~. Before diving, the mast was laid flat back, and when in submerged trim the motive power was obtained by a two-bladed propeller rotated by a hand-wheel, an arrangement that could also be used on the surface when there was not sufficient wind for sailing.

The first trials took place abreast of the Hôtel des Invalides, in the

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Seine, in a depth of water of 25 feet. Here Fulton submerged the boat to an awash condition and manœuvred about. When in this condition of trim total submergence was obtained by taking in more water ballast. A strong tide acting on the boat took her far down the stream when submerged. Such a performance very much struck the onlookers, who thought a good system of control in the vertical plane had been discovered, and this impressed them far more than the success of the experiment really warranted. The first submergence lasted some eight minutes and the second a little longer. The tide prevented any real success being obtained, as the boat could not be driven against it. The inventor then resolved to try the boat in the open sea, and a few days after these first attempts had her taken to Brest.

Some modifications were made in the lighting arrangements. The candles were found to vitiate the air too much, so a large glass scuttle was fitted into the top part of the hull of the boat to admit the light.

Fulton increased his crew from one man to three, and carried out more trials at Brest, on the 3rd June, 1801. The boat was taken to a depth of 7 metres and remained there for one hour.

A few months later he experimented with compressed air in a reservoir, and is supposed to have remained closed down for five hours. This air was charged up to 200 lbs.—not atmospheres, as so many writers say, which would mean 3000 lbs., a degree rather beyond the pumps of those days, and even fairly hard to obtain and keep in a reservoir at the present time. The flasks in use in the Holland submarines are only charged to 2000 lbs.

Fulton still worked at his explosive magazine, and the commission placed at his disposal an old shallop,* which he succeeded in blowing up with a towing torpedo containing twenty pounds of gunpowder. This is the first known instance of a ship being blown up, in European waters, by means of an explosive charge placed under water (August 1801). The trials of the "Nautilus" were quite successful, and satisfied the commissioners in everything but some few minor details, which could easily have been added in a new boat. The best under-water experiment was covering 500 yards in seven minutes and returning to the point of departure.

The maritime Prefect of Brest refused to allow Fulton to attack

* Schooner.

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an English frigate lying off Brest on the score that this manner of making war on the enemy would be visited with such reprobation that the persons who should have essayed it and should have failed would be hanged. Evidently the worthy Prefect would not have minded had the attempt been quite successful and resulted in no further complications. Many writers say that this attack was actually made, but the English "74" constantly shifted her berth and could not be surprised. Some time after the experiments referred to the inventor offered plans for a much larger boat to carry double the crew and remain under water for a longer period, but the Minister of Marine at that time, Admiral Pleville le Pelly, declared that his conscience would not allow him to have recourse to so terrible an invention. Cold water was thus thrown on Fulton from every quarter, and his inventions were regarded by all those in authority with the utmost distaste, and the extraordinary part of his want of success was largely due, not to any fault or false claim of his invention, which satisfied the requirements of the day, but to Fulton demanding that his crew should be recognised as legitimate belligerents by letters patent and granted a commission. This clause he very rightly refused to delete from the original submission. Also popular opinion of the day was against this method of warfare, and was quite incapable of grasping the enormous possibilities of Fulton's schemes. He finally received his *congé* in a letter dated the 5th February, 1804, informing him definitely that all his propositions were rejected.

Whilst the trials were taking place at Brest some considerable anxiety was felt in England at the rumours of a terrible invention that would sweep all the ships off the seas. Lord Stanhope raised the question in the House of Lords, and the Ministry of that day are supposed to have made overtures to the inventor of this deadly weapon. Whether this is true or not, a general want of confidence began to be felt in France towards Fulton, and some experiments carried out in the Seine * connected with the development of steam navigation drew little attention and suffered the same fate as his submarine boat and torpedoes. The American, quite disgusted with French methods, came to England in May 1804, and laid his schemes before the British Government.

* 1803.

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Mr. Pitt, then Prime Minister, was attracted by these new and strange proposals, and appointed a Commission to consider them, consisting of himself, Admiral Sir Howe Popham as naval expert, Lords Mulgrave, Melville, Castlereagh, Sir Joseph Banks, Mr. Cavendish, Sir John Rennie, and Major Congreve. From the first the Commission were not disposed to favour Fulton's schemes, and stated so in plain words, as they were of the same opinion as Admiral Pleville le Pelly, the French Minister of Marine. Many explosive* experiments were carried out, but they failed to make the desired impression, although demonstrated before Mr. Pitt, Admiral Holloway, and Mr. Sidney Smith. Admiral Earl St. Vincent, then First Lord of the Admiralty, fully recognised the tremendous possibilities of these inventions, but openly opposed them in emphatic language, saying "Pitt was the greatest fool that ever existed to encourage a mode of warfare which those who commanded the seas did not want, and which, if successful, would deprive them of it."

After these experiments, which clearly showed that Fulton was no fraud, it is generally supposed that offers of compensation were made to induce him to desist from his schemes; these he indignantly refused, and only accepted the actual cost of the experiments.

The following extract from Mr. Fulton's letter to Lord Grenville is interesting: "It has never been my intention to hide these inventions (torpedoes) from the world on any consideration. For myself, I have ever considered the interest of America, free commerce, the interest of mankind, the magnitude of the object in view, and the rational regulation connected with it, superior to all calculation of a pecuniary nature." Failing to get his ideas taken up in England, Fulton returned to America in 1806.

Other inventions† in connection with torpedo warfare were brought out by the American, but apparently were not wanted, therefore Fulton decided to develop his laid-aside researches in connection with the use of a motive power for marine navigation.

These ideas, as previously mentioned, received scant attention in France, but before long all Europe was astonished by the successes of Fulton in developing steam propulsion for ships. In spite of these achievements experiments with submarine boats were not

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* Blowing up of brig "Dorothy" off Walmer, Chapter XXI (Fig. 60).

† Submarine Mines, Chapter XXI.

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entirely renounced, for in 1810 Congress granted this inventor 5000 dollars with which to further his efforts. This resulted in the construction of a boat called the "Mute"; she was 80½ ft. in length, 21 ft. beam, and 14 ft. in depth. Over the whole of the upper works armoured plates were placed in order to protect her from gun-fire. The motive power was an ordinary steam-engine, and from its silent manner of working the vessel's name was derived.

Her trials were not completed when Fulton died, thus bringing to a close this ardent inventor's great works, one item of which was a large step in the effort to solve the problems of submarine warfare. He also proved that the compass was unaffected at rest or when in motion under water.

Humanitarians generally acknowledge that whilst war is one of the greatest evils of the human race, any improvement in weapons that tend to make it more deadly, and therefore not lightly undertaken, are gladly welcomed. Fulton's lofty ideas raise him to a level seldom reached by inventors, and his efforts to obtain them plainly show he lived many years before his time.

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CHAPTER V.

BAUER'S SUBMARINES *—1850.

In 1850 we again find two European countries at war, a phase of which was the rigid blockade of the German coast-line by the Danish fleet. It fell to the lot of a non-commissioned officer of the Artillery, a Bavarian by birth, named William Bauer, to bring his genius to bear on the problem of how to act secretly against the Danish fleet and prevent the havoc and hardship that a rigid blockade always imposes on coast towns.

Several influential citizens backed up the ideas of Corporal Bauer, with the result that a submarine was laid down in the yard of MM. Schuffel and Hovald at Kiel in 1850. She was hastily constructed of sheet-iron and was launched under the name of "Sea Diver" ("Le Plongeur Marin").

Her dimensions were:

26½ ft. in length;
8 „ maximum beam;
Displacement 38½ tons.

Attached to the hatchway for allowing the crew to enter were "gloves" by which a torpedo could be affixed to a hostile ship. The explosive charge was fitted so as to be fired by a primary electric battery. The motive power was obtained by revolving a wheel, geared to a screw in the stern of the boat.

To submerge the boat, water was let into the double bottoms, which were provided with suitable pumps for expelling it when found necessary to rise. Two hatches with specially fitted watertight lids allowed entrance to the boat (Fig. 6).

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* The details given in this chapter are largely derived from *La Navigation Sous-marine; Les Bateaux Sous-marins; Die Unterseeische Schiffahrt*, by Louis Hauff, Munich, 1859; *Das Bayerland*, 1901.

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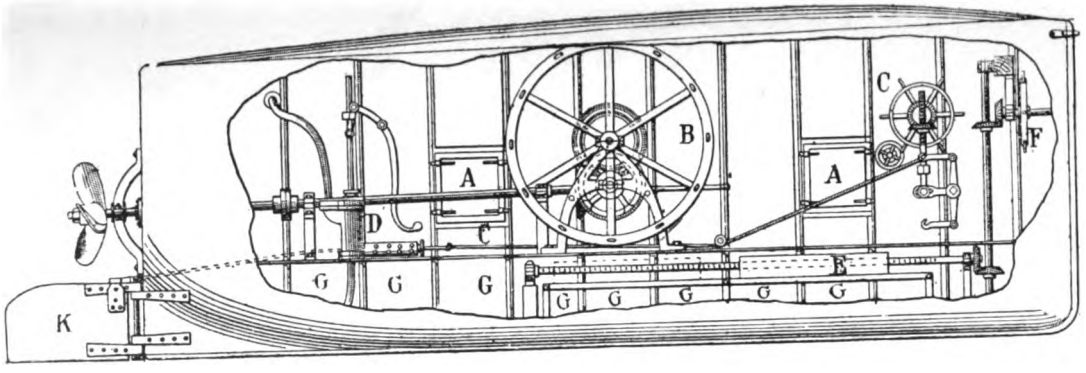

FIG. 6.—"*LE PLONGEUR-MARIN.*"

A A.—Hatches for Crew to Enter by.
B.—Hand-wheel for Rotating the Propeller.
C C.—Steering Wheel and Rods to Rudder K.
D.—Pump for Ejecting Water Ballast.
E.—Heavy Weight for Altering Longitudinal Trim.
F.—Gearing for Moving Weight E.
G.—Water Ballast Tanks.

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Water ballast was taken in until the upper deck was quite awash, then Bauer moved, whilst in motion, a heavy weight. This gave the boat the necessary inclination, and as soon as she started to go under he moved it back, and so on, consequently a succession of small dips were taken. This was quite a new departure from the oars of Drebbel and the vertical screw of Bushnell.

The boat suffered from the inexperience of the constructors, and that the inventor was unfortunately persuaded to alter certain details in the designs by his well-wishers at Kiel.

In December 1850 Bauer made a successful feint with his boat at the enemy's ships, which had the desired effect of making the blockading fleet recede to a more respectful distance, the moral effect of a submarine at that time being very great; and once the secret of this boat's existence became known the ships could only be seen in the offing.

Further trials showed the weakness of construction. The following is an extract of an exciting experience taken from *Das Bayerland*:—

"On the 1st of February, 1851, at Kiel, at 9 o'clock in the morning, Bauer, with two seamen, went down, and for some time the 'Sea Diver' went all right, but on reaching the deepest part of the harbour the sheet-iron in the stern gave way and they commenced to sink lower and lower, in spite of all efforts to drive the water out of their reservoirs. The iron ballast having slipped forward, they went down in a vertical position; the partitions, under the pressure of the water, seemed about to yield, and all the machinery became dislodged. The boat finally rested at the bottom in 18 metres of water.

"The situation seemed desperate; but Bauer kept his head, well knowing that at all hazards they must extricate themselves from the damaged boat. He ordered the men to again let the water into the reservoirs, and from them flood the whole interior, so that by the compression of the air in the boat as the water entered, it would gradually become equal to the exterior pressure on the hatches, which could then be opened, and the men get forced up to the surface.

"The sailors, who up till now had shown great courage in their ignorance, did not understand Bauer's orders, refused to obey, and even began to abuse him. He in his turn began to abuse them, and

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it was only by threats and entreaties that he managed to convince the men that it was the only way to save their lives. They started again to work by the dim light which came through the portholes. By judicious remarks Bauer raised them to such a pitch of excitement that they swore if Bauer could only get them above the surface again, and chose to construct a new submarine, they would be the first to follow him.

"After a great many efforts and anxieties, chiefly caused by the men on the surface throwing anchors and grapnels which threatened to destroy their portholes, the water entering compressed the air in the interior of the boat to such an extent that it burst open the weakly constructed hatches with the result that Bauer and his two companions were shot up to the surface like corks out of a champagne bottle. It was then 3 o'clock in the afternoon; the boat had been under for 5 hours. They were received by enthusiastic crowds, who thought that the crew would never be seen again. The 'Sea Diver,' which had cost 13,800 francs, remained at the bottom."

Efforts were made to raise her, but it was not until 1887 when a dredger came across a large obstacle, which—thanks to the efforts of M. Bagge—on being successfully brought to the surface, and on removal of the seaweed, barnacles, etc., turned out to be Bauer's submarine.

For many years this strange vessel formed an interesting object in the courtyard of the Naval School at Kiel, where the illustration (Plate 9) was photographed for this work.

Towards the end of 1906 this small submarine was taken to the Oceanographical Museum in Berlin, where it will no doubt form an interesting relic in that collection.

Bauer was very much discouraged by the hostile criticisms levelled at him, which were most unfair, considering he was the only individual who had made a really good attempt of an ingenious nature to break down the blockade, and, instead of being voted further assistance from his own country to perfect a stronger boat, he was driven by want of money to approach the Austrian Government with the plans of an improved submarine.

The Emperor appointed a Commission at Trieste, the members of which were so much taken with the Bavarian's ideas that they voted him 106,000 francs with which to continue his experiments. Unfortunately the Minister of Commerce took it into his head that

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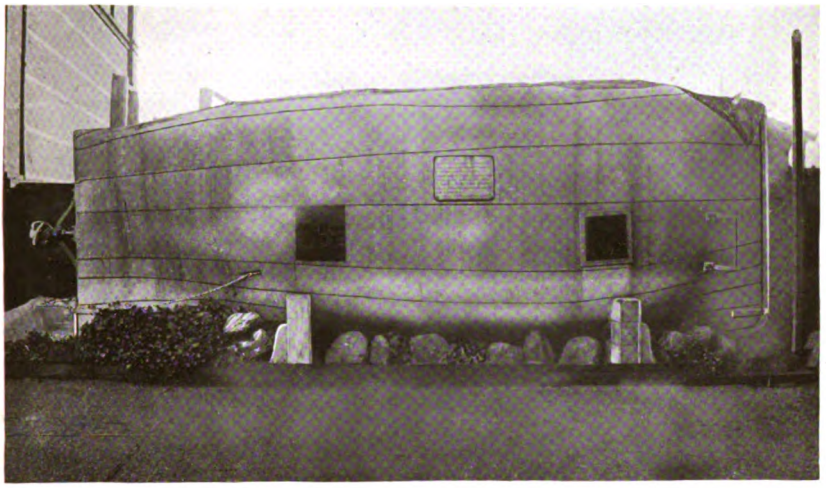

PLATE 9.—"*LE PLONGEUR-MARIN.*"

Lost in Kiel Roads, Feb. 1st, 1851—Raised in 1887.

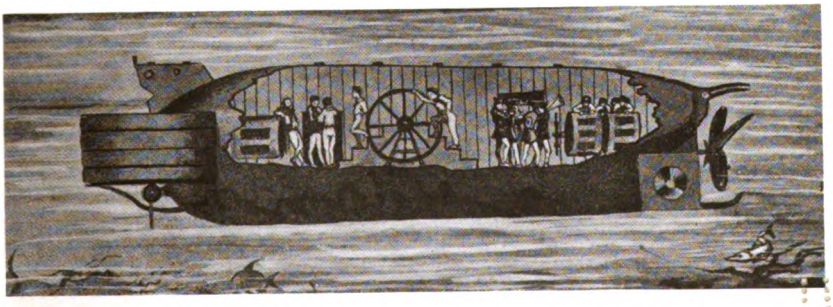

PLATE 10.—"*LE DIABLE-MARIN.*"

Musicians playing under water during the Coronation of Alexander II., 1856.

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this invention was contrary to all the laws of science, and his decision overruling the report of the Commission was upheld by the higher council of the Austrian Government. Once again Bauer was stranded in the midst of a political squabble which then ensued, and finding himself being used as a sort of buffer between the two parties, he decided to seek fresh fields for his invention. This brought him to England, where he was assisted by the Prince Consort to come in touch with some of the leading men of that time, amongst whom was a celebrated engineer named Scott-Russell. Bauer's various ideas were submitted to this gentleman, which resulted in designs of a sloop of war and submarine boat being got out. Unfortunately the Bavarian did not get on with his new patrons, and, after having been bled of his ideas, from which plans, etc., were made, Bauer was told politely he was no longer required.

In the very workshop from which he had been dismissed, Scott-Russell set to work and built a submarine,* the great engineer modifying the prepared designs to his own ideas.

The results of this modification are interesting and are given in the exact words of Admiral Sir Astley Cooper-Key, when speaking at the Royal United Service Institution in 1896. "A submarine boat, which was considered to have been of considerable importance during the Crimean war, was proposed by Mr. Scott-Russell, one of the most eminent engineers of the day. It was thought highly of by the Government, and Lord Palmerston, then Prime Minister, sanctioned an expenditure of £7000 on its construction and trial. Sir James Hope, Sir James Sullivan, and I were appointed to report on its capabilities. I need scarcely say that it was a failure; but it serves to illustrate the great advance that Mr. Nordenfelt has made in the submarine boat he now proposes. I did not like the look of Mr. Scott-Russell's vessel. It was merely a large diving-bell, like an inverted boat. Two men were supposed to go in it. It was to be lowered by admitting water into a compartment, and to be raised by pumping it out or by blowing it out with compressed air. It went down to the bottom with the men under it; they were to walk on the bottom and propel the boat by pressing against thwarts fixed to the under-side of the boat. The boat looked rather doubtful as to its rising to the surface, having a long strop and thimble attached,

* 1854–5.

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and buoy with long buoy rope. The boat went down and remained there twenty minutes; a tackle was sent down hooked to the strop, and up came the boat just in time. They were bold enough to try it a second time, but with no greater success. The second time it came up suddenly, blew like a whale, and capsized. I mention this to show that many years ago the submarine boat was considered an important weapon of offence. In that case it had a special object."

The gallant admiral—probably not wishing to discourage Mr. Nordenfelt, who was present, having just read a paper on his submarine boats—omitted to say that the Scott-Russell vessel drowned a considerable number of men in one of her preliminary efforts.

Mr. Scott-Russell would have been wiser had he continued his experiments in other directions rather than interfere with a science in which he had little theoretical and certainly no practical knowledge, added to which he disdained the advice of the practical Bauer.

An attempt was now made by Bauer to persuade the United States Naval Department to consider his invention, but this was unsuccessful, so the designs were then laid before the Russian Government, with the result that a boat was constructed at the Leuchternberg works, St. Petersburg, from funds furnished by the Grand Duke Constantine, of these dimensions:

Length . .	52 ft.
Maximum beam	12 „
Maximum depth	11 „

The boat was launched towards the end of 1855 under the name of "Le Diable Marin," and in the early spring of the next year, commenced trials (Plate 10).

The Germans were not pleased with Bauer for offering his invention to the Russians, but as they did not appreciate him in his own country we must admire the inventor's perseverance in forcing his ideas to the notice of the chief nations. The Russians were jealous of the Bavarian and baulked him on every possible occasion, but fortunately one of their officers kept the Russian crew in order and encouraged Bauer to carry out a long series of experiments in 1856. As a great secret was made of these trials it is hard to obtain

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any reliable information concerning them. In all, Bauer is supposed to have made some 134 submergences, during which he studied the behaviour of the compass and confirmed Fulton's observation that the magnetic force of the earth on the needle was apparent at various depths; he ascertained that this force was sometimes augmented or diminished when the boat was at a great depth near the bottom, according to the locality.

The Bavarian was a good advertiser; and during the coronation of Alexander II, on September 6, 1856, he took several musicians under water, and when the guns at Cronstadt commenced the royal salute, the band beneath the surface of the water struck up the National Anthem.

This could be plainly heard by those on board the various ships in the harbour, and showed how easily sound-waves are propagated in water, a phenomenon only now being made use of for submarine signalling. Bauer was the first to recognise the application of the principle of the longitudinal shifting of weights. In the "Diable Marin" longitudinal weights were supplemented by horizontal rudders.

The success obtained with his submarine boat did not contribute to the Bavarian's popularity; the Russians nicknamed him "Little Corporal." His want of manners were even held up to ridicule. Bauer being of humble birth, it would have been surprising if his training had showed him up to any great advantage.

One more experiment is left to chronicle. Bauer took his boat two or three miles beyond Cronstadt and, by order of the authorities, had to pass under a ship at anchor. Unfortunately the water was shallower than the inventor was given to understand, and she hit a mudbank. In the mishap the screw got choked up with seaweed and mud. Considerable difficulty was experienced with the seaweed. The crew managed to get out of the boat without loss of life, but it took Bauer several weeks before the boat was in working order again. She, however, did not long survive this accident, and was subsequently lost off the coast near Ochda.

The authorities, instead of abandoning submarines after this loss, invited Bauer to superintend the building of a larger boat, but the poor Bavarian was so disgusted with the ignorance of the Russian officers in subjecting him to petty annoyances, etc., that when, after repeated applications, permission to leave the country was given, he

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lost no time in bidding farewell to his patrons. Bauer went to France, and we next hear of him petitioning Napoleon III for pecuniary assistance, which was generously granted. Some years later he drifted back to Germany. His next venture was an attempt to raise the wreck of a ship in Lake Constance. This vessel was actually brought to the surface by the skilful Bavarian, but foul weather came on, the hawsers parted, and once more his efforts were thwarted.

This was the final straw. Poor indomitable Bauer gave up at last; shattered hopes, no money, and bad health were the rewards for all his labours. As a provision for the latter portion of his life, a small pension was obtained for him from his Government, and he died in 1875. A monument is erected to Bauer in Munich, which stands to-day as a reminder of a man of great perseverance, resourceful and courageous, to whom much credit is due for the practical manner in which he advanced many schemes and brought them, in spite of almost insurmountable difficulties, to a successful issue, and thereby furthered the evolution of the submarine boat.

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CHAPTER VI.

THE AMERICAN "DAVID" SUBMARINES—1862-4.

JUST over forty years ago another great struggle was taking place, a war that threatened to make two countries of that now known as the United States of America. In 1861 the existing Government of that country was in almost a bankrupt condition, consequently the navy had been greatly neglected and very few ships were available for either the northern or southern States, then in the throes of civil war.

The former rose to the occasion and hastily constructed a large number of ships; river-service steamers were cut down and provided with armour-plate protection, also submersible monitors were built which could lessen their buoyancy by taking in water ballast, and therefore offer as little target as possible to the gun-fire of the forts manned by the Southerners.

With these hastily constructed vessels the Northerners established, shortly after hostilities had broken out, a rigid blockade of the chief ports and principal rivers of the South. To make this effective the fleet operating before Charleston was strengthened by ship after ship as fast as they could be completed.

The Federated States, in April 1863, instructed Admiral Dupont to capture the forts off the port of Charleston. With seven monitors, the armoured submersible ship "Keokuk," and the new "Ironsides," a broadside armoured ship of sixteen guns, he commenced operations against Fort Sumpter; but after an attack of two hours his ships were so severely handled that the order to retire had to be given. The guns of the forts fired a large number of projectiles, but few lives were lost on board the vessels; they were, however, severely knocked about, with turrets jammed, and much structural damage done. After such a severe repulse, the navy of the Federals did very little bombarding and remained comparatively inactive for several months.

A close blockade was however still maintained of the chief harbours

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and navigable rivers. The Southerners had very few ships at their disposal with which to compete against the new ironclads, etc., that were being brought against them, and this once more forced native ingenuity into prominence. The weakest side usually takes drastic means, and on this occasion reliance was placed on the torpedo for breaking up the blockade.

Every known kind of submarine mine* was used for defensive purposes, while several boats of various types were hastily constructed, some of which had considerable success in their short lives.

As the boats were designed to blow up the largest ships of the Northerners they locally went under the biblical name of "Davids."

The first boat was built of a cylindrical form in the centre with conical ends and constructed of boiler iron, having a length of 54 ft., beam 5·6 ft., and height 5·6 ft. in the centre (Fig. 7).

This "David" was provided with an ordinary boiler which generated steam for a marine engine coupled direct to a shaft connected to the propeller.

For offensive purposes water ballast was taken into tanks and the whole boat submerged into an awash position. In this condition of trim only some 10 ft. in length of superstructure could be seen. She then looked like a large baulk of timber with a funnel coming out of it; the funnel being telescopic could be lowered several feet, so as to make the boat as nearly invisible as possible. A torpedo was carried consisting of a copper case with semi-spherical ends, 10 in. in diameter and 32 in. long, containing 134 lbs. of gunpowder on the end of a spar (Fig. 4), provided with seven chemical fuses, which exploded the charge on coming in contact with an enemy's ship.

These steam "Davids" were not constructed to dive, but took in water ballast for running on the surface in an awash condition. The first boat was successfully launched and manned by a volunteer crew under Lieutenant Paine. In one of the first trials a passing steamer caused a heavy swell to break over the boat when the hatch was opened. This swirled down the opening and swamped the boat. The officer was the only one of the crew saved. Notwithstanding this mishap the boat was raised and a second volunteer crew, under Lieutenant Glassell, after a few trial trips, essayed an attack at 9.15 p.m. on the 5th October, 1863, against the Federal ships off

* See Chapter XXI.

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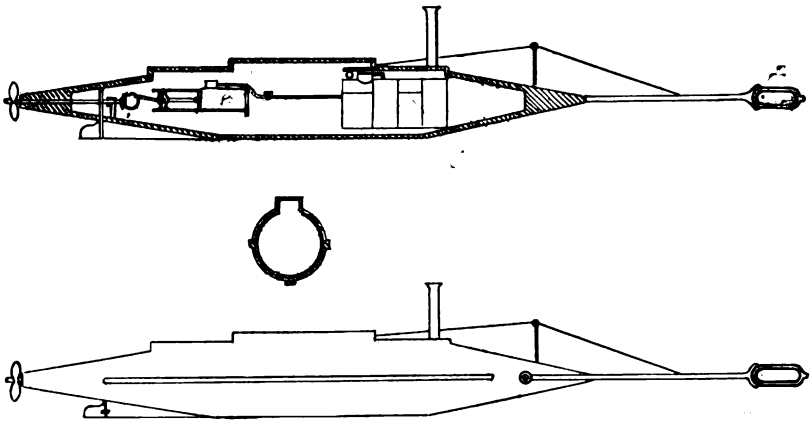

FIG. 7.—*A STEAM "DAVID."*

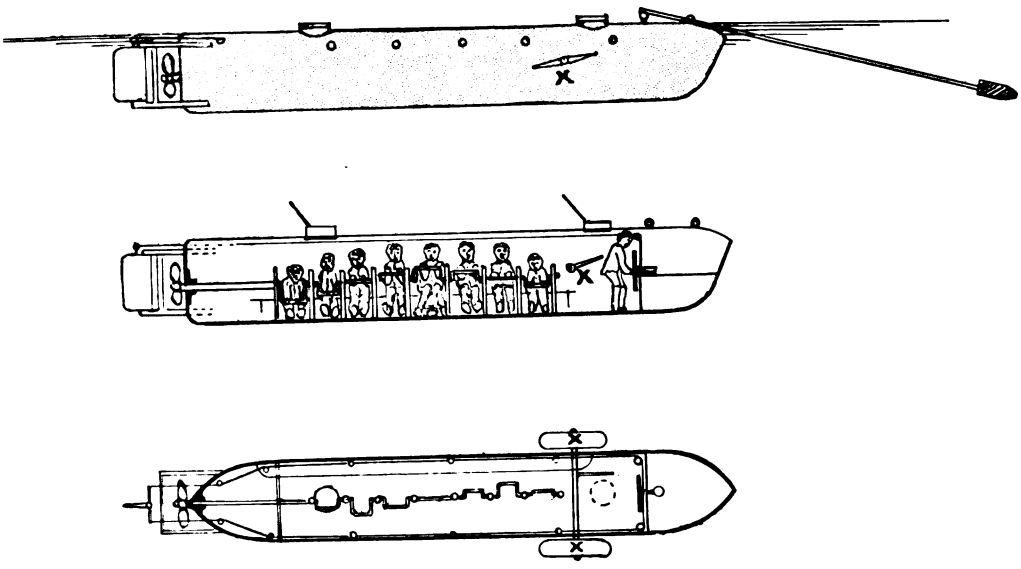

FIG. 8.—*A HAND-PROPELLED "DAVID" HYDRO-PLANES SHOWN AT X.*

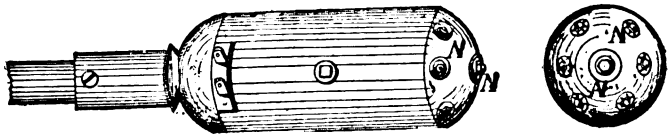

FIG. 9.—*THE SPAR TORPEDO OF A "DAVID."*
The Chemical Fuzes for exploding the charge are shown at *N*, *N*.

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Charleston. He fell in with the "Ironsides," a ship very much dreaded on account of her heavy attacks on the forts. All these ships had been specially warned to look out for submarine attacks; and after dark the "Ironsides" shifted her anchorage every night.

The officer of the watch on this particular occasion saw a plank with a cylindrical pole on it coming towards his ship. The quartermaster was ordered to hail the object. The reply was a volley of musketry from the open hatch of the submarine; this killed one Federal officer. The object came closer and closer to the ship. Shortly afterwards a heavy explosion occurred which shook the vessel severely, threw a column of water on the spar deck, flooded the engine-room, broke one man's leg, and started many leaks, with some external damage above the water-line.

A spar torpedo was used in this attack, but, being exploded too near the surface, the damage was not so great as might have occurred had the charge been more submersed.

In the explosion the submarine was swamped; the lieutenant and two others managed to save themselves by swimming clear of the boat and getting picked up by a coaling schooner. The following is an independent account of this attack, which we have every reason to consider perfectly reliable, and shows some considerable damage was done to the "Ironsides." Hobart Pasha writes *:—

"I remember on one occasion during the war, when I was at Charleston, meeting in a coffee-room at that place a young naval officer (a Southerner), with whom I got into conversation. He told me that that night he was going to sink a Northern man-of-war which was blockading the port, and invited me to see him off. I accompanied him down to his cigar-boat, as he called it, and found that she was a vessel about forty feet long, shaped like a cigar, on the bow of which was placed a torpedo. On his stepping on board with his crew of four men, his boat was immersed till nothing but a small piece of funnel was visible. He moved off into the darkness at no great speed, say at about five miles an hour. The next evening, on visiting the coffee-house, I found my friend sitting quietly smoking his pipe. He told me that he had succeeded in making a hole in the frigate which he had attacked, which vessel could, in fact, be seen

* *Blackwood's Magazine.*

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lying in shallow water, some seven miles off, careened over to repair damages. But he said that, on the concussion made by firing the torpedo, the water had rushed in through the hatches of the boat and she had sunk to the bottom. All his men were drowned.* He said he didn't know how he escaped himself, but he fancied that he came up through the hatches, as he found himself floating about, and swam on shore. This affair was officially reported by the American blockading squadron, corroborating the fact of the injury done to the frigate, and stating that the torpedo-boat was got up, with four dead bodies in her hold. Here is one system which might be utilised in naval warfare, if perfected; and I am given to understand that a submarine torpedo-boat is already invented by Mr. Nordenfelt."

Early in the year 1864 Admiral Dahlgren, commanding the Northern squadron, was warned by spies that an improved submarine † (Fig. 8) had been launched, of a slightly different type from that which attacked the "Ironsides." He ordered extra look-out precautions to be taken in the ships, but few of his officers thought the submarine would be able to reach the outer anchorage of Charleston harbour.

The Southerners were quite aware of this opinion, and determined at all hazards to make an attempt to reach the ships and blow up as many as they could with their new weapon.

On the night of February 17th they succeeded in getting the boat over the bar, and directed her towards the nearest vessel. This turned out to be the new wooden ship "Houstanic." The officer of the watch and look-outs, soon after 8 p.m., saw, a few hundred yards off, what they thought was a small boat making towards them. On nearing the ship the craft was hailed, but no answer came. The crew were at once sent to quarters; but it was then ascertained the pivot-guns could not be depressed sufficiently to hit the object if they had been fired.

The order was next given to slip the warship's cable. The stranger came on and touched the side. As the propellers of the big ship moved, a loud explosion followed the grazing and cracking sound of the breaking spar, which carried the torpedo from the bow of the submarine. The "Houstanic" had a large hole driven in her star-

* Other accounts state that two of the crew besides the captain were saved.

† Usually known as the "David" of Hunley.

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board side abreast of the mainmast, and sank until the hammock nettings were just awash when the keel was on the bottom. Many of the crew were saved by the boats of the "Canaladiagua," which was anchored near by, but an ensign and several men were drowned.

Nothing more was seen of the "David," and it was generally supposed she escaped until, some years later, when divers were sent down to examine the wreck of the "Houstanic," they found the gallant little "David" lying alongside the big ship with the remains of the crew of nine men on board.

This boat was propelled by hand-power and not steam, as in the early boats. The crew of eight men worked on a sort of pump-handle for turning the propeller (as shown in diagram). The air-supply was sufficient to last the crew two to three hours; and we notice in connection with this boat that hydro-planes were fitted externally at the foremost end to assist in keeping the boat low in the water and for making small dives.

The United States steamer "Minnesota" was attacked by a steam "David" when anchored off Newport News, Va., April 9, 1864. The officer of the watch on board the "Minnesota" saw a boat adrift on his port beam, hailed her, and she replied "Roanoka."

A tug acting as guard-boat was hailed to examine the boat. The stranger neared the large ship; she was very low in the water, almost awash, with no sign of any oars, but the quartermaster heard her puff. The tug was ordered to run her down if no further replies were received, and the sentries on the forecastle fired several volleys at her; then a loud explosion occurred. The crew beat to quarters, and in the confusion the "David" escaped. A considerable amount of damage was done structurally to the steamer, and large quantities of stores were destroyed by water through leakage, etc.

The following despatch* was captured in a telegraph station on James River a few weeks later:—

"Hon. S. R. Mallory, Secretary of Navy,
"Navy Department, Richmond, Va.

"Passed through the Federal Fleet off Newport News and exploded fifty-three pounds of powder against the side of the flagship

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* *Submarine Warfare, Offensive and Defensive*, by Lieut.-Commander Barnes, U.S.N., New York, 1869.

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'Minnesota' at 2 a.m. 9th inst. She has not sunk, and I have no means of telling the injury done. My boat and party escaped without loss under the fire of her heavy guns and musketry, and that of a Gunboat lying to her stern.

"HUNTER DAVIDSON.

"*April* 11*th*, 1864."

This "David" differed slightly from the "Davids" of Charleston, as she was a steam-pinnace into which water ballast-tanks were built and the whole upper works plated over with armour. With the tanks full, only a small turtle back was visible, with a man-hole and aperture for funnel, which was capable of being lowered.

Another "David" attacked the steamer "Memphis" at 1 a.m. on March 6, 1864, in North Edisto River, and succeeded in getting under her quarter. The ship's engines were moved, and it is believed one of the blades of her propeller struck the torpedo spar of the "David," and broke it, consequently the attack failed.

On conclusion of the war a large number of "Davids" were found at several places in various stages of construction. These boats are usually looked upon as not being very successful. To injure three ships and sink a fourth, besides keeping the blockading squadron continually on the move, for a loss of three or four crews, was well worth the patriotic sacrifice, and helped to prolong for a considerable time the issue of the war.

In studying the value of semi-submarines of large displacement as modern fighting units, we notice that they possess the advantage of being able to decrease the target offered to hostile gunfire by admission of water ballast, but at the same time they increase the under-water target for hostile torpedo craft to fire at.

Large semi-submarines are therefore not advocated as weapons in modern schemes of defence for that reason, and also because they cannot suddenly become invulnerable to any form of attack by invisibility—the great power of the submarine proper.

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CHAPTER VII.

Garrett and Nordenfelt's Submarines*—1878–87.

In 1878 Mr. Garrett, then a curate in Liverpool, took up the study of under-water navigation, and had built a small submarine 14 ft. in length with a maximum diameter of 5 ft.; the hull was made of steel plates, forming an egg-shaped structure with rather pointed ends. In the centre a circular conning-tower was constructed, having the usual opening hatch, glass scuttles or port-holes for looking ahead, on the beam and right aft (Fig. 10).

This boat, similar to one of the first Russian designs,† was fitted with two arms for catching hold of objects when below the surface, these were made of leather well soaked in oil to keep them pliable and soft for use.

The boat was submerged by taking water ballast into the tanks O, shown at the bottom of the vessel, until the weight of the volume of water displaced equalled the weight of the boat. When this state of equilibrium was established the operator could turn a handle for working a piston in or out of the cylinder S that was in direct connection with the sea; as the piston was withdrawn the water entered through a strainer into the cylinder; this was admitted until the boat obtained downward momentum.

The method was crude, but it answered fairly well in the first submergences. The motive power was obtained by turning a hand-wheel connected direct to the screw propeller.

These initial experiments, carried out in the Liverpool docks, were very important, and showed Mr. Garrett clearly that, to obtain moderate success with a submarine, the volume of air in the boat should be sufficient to last the occupants a considerable time without

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* The information in this chapter has been largely taken from the papers of the late Lieut.-General Sir Andrew Clarke, R.E., one of the British delegates at the trials of the first Nordenfelt boat, Landskrona, September 1885.

† Chapter XIII.

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having recourse to any stored supply or other means of purifying the vitiated air.* This requirement, based on actual experiment, led to the design of a larger boat, the construction of which was placed in the hands of Messrs. Cochrane, of Liverpool, towards the end of 1879. The maximum diameter of the first boat was adhered to in the new design, but the hull, instead of being egg-shaped, was made cylindrical in the centre with pointed ends, the length being increased to 45 ft. Mr. Garrett christened the boat "Resurgam" (Fig. 11).

Water ballast was taken into the tanks in the bottom for lessening the buoyancy; but instead of destroying all buoyancy, as in the first boat, and depending on maintaining equilibrium by drawing in or pushing out a piston, Mr. Garrett kept a small reserve of buoyancy of a little over 100 lbs., and depended on hydro-planes, as fitted in one of the American "Davids," † for forcing the boat under water when in motion. The hand motive power was replaced by steam power, a boiler and engine being provided for surface propulsion; for submerged running a full head of steam was raised, and the latent heat given off was utilised in heating water stored in special tanks, on the principle of Lamm's fireless locomotive; this provided sufficient energy for working the engines for a ten-mile run under water at a speed of from 2 to 3 knots ~~or more~~. The boat did some fairly successful preliminary trials in the Birkenhead float with a crew of three men; but when undertaking deep-sea experiments she was unfortunately lost off the Welsh coast before any great experience of her capabilities could be ascertained. The lessons learnt in submarine navigation by Mr. Garrett might at this stage have come to an abrupt ending had not necessity caused him to approach Mr. Nordenfelt, the well-known gun expert, who was looked upon at that time as the patron of embryo and needy inventors. Mr. Nordenfelt took the invention warmly up, with the result that several submarine boats were built, which we propose to examine in some detail, because they were a very bold and decided attempt to bring this new class of vessel into prominence for coast protection. In striking out such a novel line of construction on a large scale Mr. Nordenfelt argued that, although submarine mines placed at the bottom or floating anchored had been adopted generally, they were acknowledged not to fully satisfy the

* See Chapter XX. on Fumes. † Fig. 8.

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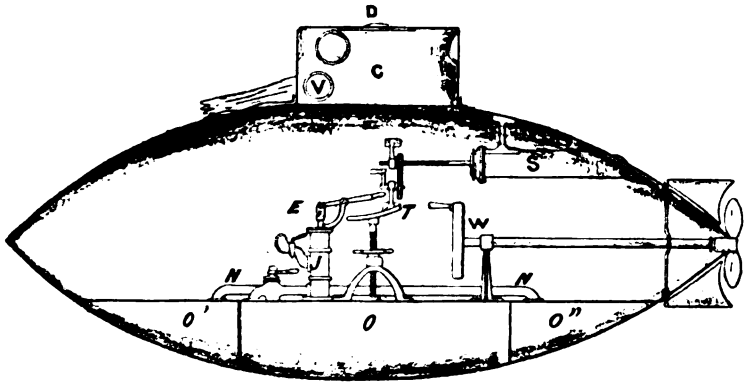

FIG. 10.—*GARRETT'S FIRST SUBMARINE*, 1878.

C.—Conning Tower.
D.—Entry Hatch.
J.—Hand Pump.
O', *O*, *O"*.—Water Ballast Tanks connected by Pipe *N*.
S.—Compensating Cylinder.
T.—Vent Valve.
V.—Arm Holes, fitted with Leather Gloves.
W.—Hand Wheel for rotating Propeller.

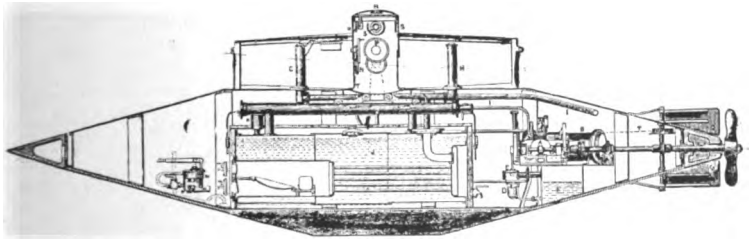

FIG. 11.—*GARRETT'S "RESURGAM."*

A.—Cylinder.
B.—Condenser.
C.—Root's Blower.
D.—Air and Circulating Pumps.
E.—Feed Pumps.
F.—Hot Well.
G.—Air Pipe.
H.—Smoke Escape Valve.
I.—Air Pipe to Blower.
J.—Boiler.
K.—Safety Valve.
N.—Steering Wheel.
Q.—Vertical Rudder.
R.—Conning Tower Hatch
S.—Scuttles.
T.—Rudder Chains.

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requirements for port defence, because they were immovable, and were exposed to be picked up by the enemy.

The towed torpedoes of the "Harvey" class had not given satisfaction, and the spar torpedoes could only be used under very exceptional circumstances. The Whitehead and Schwartzkopf fish torpedoes were then the only ones which gave any hope of usefulness by future development. Apart from the faults and difficulties in the construction and management of the fish torpedo itself, there appeared to be an almost insuperable difficulty in carrying it, with any degree of certainty, up to the short distance at which it could be considered infallibly effective. It seemed to Mr. Nordenfelt, therefore, of great importance to construct a means of carrying, with greater safety, the fish torpedoes up to such a short distance from the vessel to be attacked, as that the torpedo could not fail to hit.

The surface torpedo-boats at that date were met by machine-guns, which made their attack in daytime almost impossible; and the improvements in the direction of greater speed and thicker protection of their vital parts had been met by greater power and longer range of the quick-firing machine-guns, while their larger dimensions offered a target more easily hit. Mr. Nordenfelt thought a much greater chance would be given for carrying the Whitehead torpedo within striking distance if, instead of trying to rush the distance by many boats, all the time exposed to the destructive fire from machine-guns, he could carry the torpedo secretly up to this distance without the probability of being seen at all, and without any probability of being struck by the enemy's projectiles, even if seen.

With these ideas, and Mr. Garrett's practical experience to fall back upon, a submarine boat was designed and built at Stockholm of the following dimensions:

Length . . .	64 ft.
Beam . . .	9 „
Beam over sponsons .	12 „
Maximum draft . .	11 „
Displacement . .	60 tons.
Speed on measured mile	9 knots.
Range without re-coaling	150 miles.

The hull was built of iron plates $\frac{9}{16}$ of an inch in thickness on the underneath portion amidships and $\frac{6}{16}$ towards the

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ends and upper parts, the frames were circular and turned up, of angle-bar, 3 in. by 3 in. by $\frac{3}{8}$ in., placed 2 ft. apart (Plate 11, and Fig 12). By this arrangement it was considered that the boat would stand a submergence of about 50 ft. without distortion.

The submarine was designed to lie on the surface of the water, with the conning-tower and about 3 ft. of turtle back out of water. The complete form of the boat is shown on Plate 11. When trimming the boat for diving, water ballast was taken in by filling the 4-ton cold-water tank in centre of the boat; this brought the upper deck awash, leaving about 600 to 800 lbs. of buoyancy, provided by the conning-tower being out of water.

Mr. Nordenfelt recognised the desirability of always keeping this reserve of buoyancy, and to force the boat under water in such a condition of trim two vertical propellers were placed, one on each side, in the middle of the boat in a sort of sponson; these were driven by a 6-H.P. double-cylinder engine; a variation of speed of these depth-controlling propellers could be obtained by a hand arrangement for throttling the steam supply. Also Mr. Nordenfelt arranged, in addition to controlling the depth by hand, a means for automatically throttling the steam supply to the small engine. To do this a valve was fitted, held open by a weight; the piston of the valve was in direct communication with the sea. When a depth was reached which gave a pressure greater than the weight, the valve shut, the engines stopped, and the boat, by virtue of her reserve of buoyancy, rose until the pressure due to the depth diminished and the weight once more opened the valve. Before admitting water ballast to place the boat in diving trim, the ash-pit and furnace doors were closed, funnels lowered, and all apertures sealed down.

As soon as sufficient water was taken into the ballast-tank to bring the boat awash, the vertical propellers were started; these screwed the boat under the surface of the water, overcoming the upward force due to the reserve of buoyancy.

This submarine, unlike the American "Holland" type,* could be forced under the surface without proceeding at speed, and still keeping a reserve of buoyancy.

The American boat can only do this statical submersion by destroying all buoyancy. The rudder for controlling the boat's

* Chapter XI.

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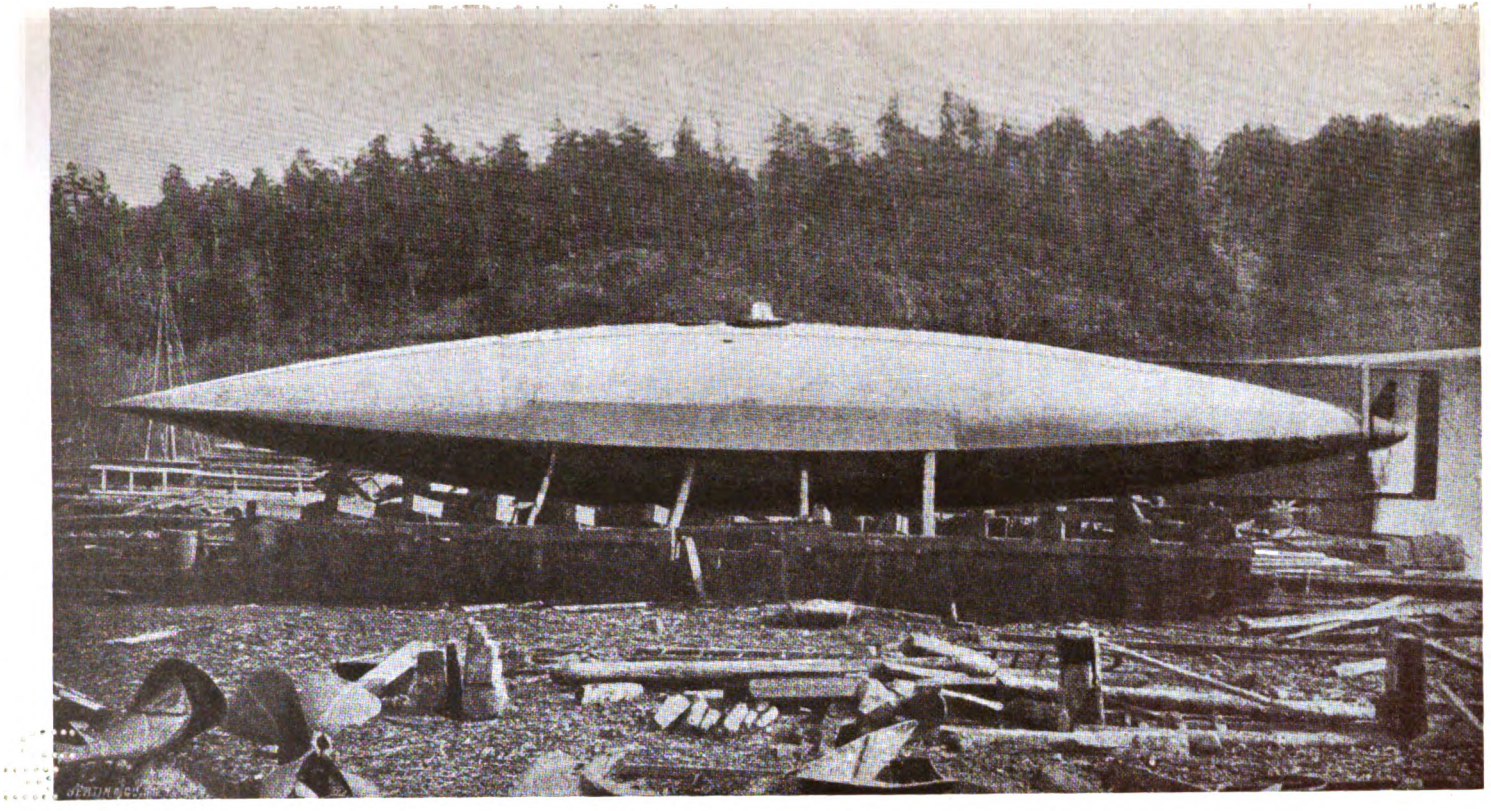

PLATE 11.—"*NORDENFELT I.*" *ON THE STOCKS AT STOCKHOLM*, 1885.

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ordinary direction was of the usual vertical type and placed abaft the propellers.

On each side of the bow were placed two hydro-planes to assist in controlling the depth-line; on coming to the surface the water could be ejected by pumps or blown out with steam pressure. The armament consisted of a single barrelled Nordenfelt 1-in. gun, which was shipped on the foreside of the conning-tower, also a Whitehead torpedo carried in a discharging tube placed externally to the hull in the bow

The propelling engines were surface-condensing type of 100 H.P., pressure 100 lbs. to square inch, with cranks placed at an angle of 90°. The boiler was an ordinary return-tube marine type with one furnace. For the motive power when submerged the latent heat obtained from the steam was stored in hot-water tanks on Lamm's system, as in Mr. Garrett's "Resurgam." The amount of heated water was 8 tons, this provided sufficient energy to give an under-water range of 15 miles at 4 knots, and arrangements were made for the smoke being blown out under water if necessary when running on the surface.

The first trials were carried out in Sweden, between the 21st and 25th of September, 1885, in presence of a large number of notabilities and representatives from nearly all the chief maritime powers. The boat had been launched at Stockholm, and on completion was towed to Landskrona, this being considered a more suitable locality for the first experiments. The programme presented to the delegates consisted of:

1. Running a long course on the surface of the water in light condition.

2. Running a course on the surface with the conning-tower cupola alone visible, the whole hull being entirely out of sight.

3. Running under water completely submerged.

These trials were carried out with moderate success.

In the last series, through a variety of causes, the dives were not very successful, as they were of only a few minutes' duration; on one occasion the boat remained below for five minutes and touched bottom.

The best dive, in which a fairly even depth-line was kept, lasted three minutes, but unfortunately one of the horizontal rudders had become bent by fouling a towing-hawser when taking the boat out of Landskrona harbour, and then an engineer got hurt, which in some

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measure accounted for the poor results obtained when totally submerged.

However, the general impression of the delegates on leaving was very favourable to the boat as a semi-submarine craft running with the conning-tower above water, but not so favourable as to the boat's diving capabilities.

Mr. Nordenfelt gathered most valuable data from these experiments, particularly in regard to the air, no extra supply being provided, as the volume contained in the boat was considered sufficient for the crew. In one breathing experiment the men were sealed down and kept entirely submerged for six hours, and no diminution of a candle flame could be noticed at the end of this long test.

The boat had one disadvantage. Should the joints on the front of the furnaces or smoke-boxes allow the escape into the boat of any of the products of combustion of the coal, the effects of the carbon-monoxide and carbon-dioxide were soon evident upon the crew, although they were not all equally sensitive to these insidious poisons. Nothing was ever observed in the way of actual smoke, but the men in the boiler room became drowsy and once or twice unconscious. A breath or two of fresh air on deck soon brought them round again. Should, however, any of the crew get what they called "smoke poisoning" badly, their services had to be dispensed with for several days. On one occasion Captain Garrett was poisoned by these fumes and rendered quite incapable of duty for nearly three weeks.

During the long series of trials in Southampton Water and the Solent, great care was taken in making the joints, so as to minimise the chance of fumes percolating into the interior of the boat.

The data obtained from these trials were embodied in the designs of the boats then being constructed in England.

The "Nordenfelt I" was sold to Greece in 1886 for £9000. All the conditions were satisfied during some further trials carried out in the Bay of Salamis before completion of purchase.

In 1887 Mr. Nordenfelt secured an order for two of his submarine boats from the Turkish Government; these were laid down near Chertsey and named "Abdul Medjid" and "Abdul Hamid." The details are:

Length	100 ft.
Beam	12 „

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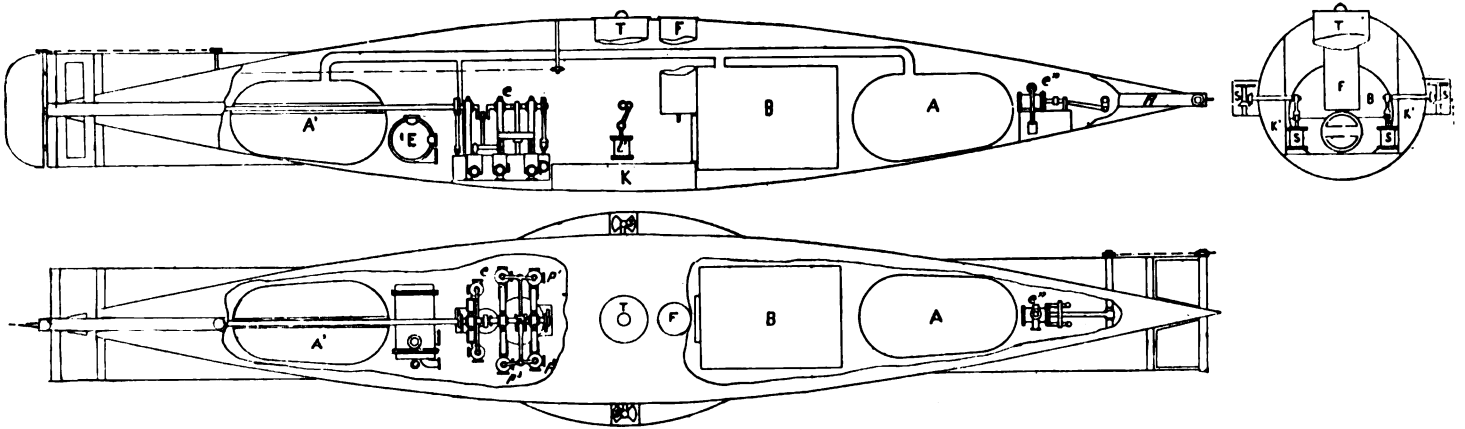

FIG. 12.—"*NORDENFELT I.*"

A A'.—Hot Water Cisterns.
B.—Boiler.
F.—Funnel.
E.—Condenser.
c.—Compound Engine.
c''.—Engine for working Horizontal Rudders.
T.—Conning Tower.
P1 P2 P3.—Pumps.
K'.—Water Tanks.
K.—Buoyancy Tank.
L t S.—Engine for working Vertical Screws.
R.—External Torpedo Tube.

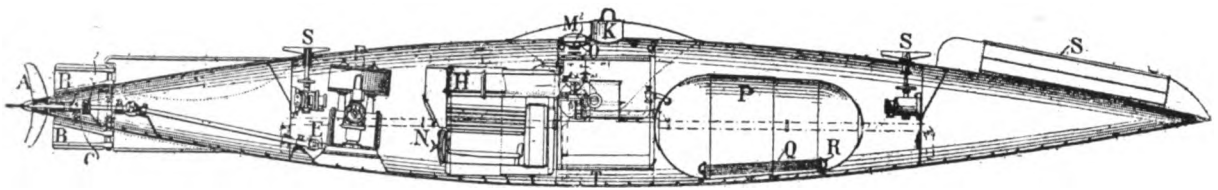

FIG 13.—"*TURKISH NORDENFELT.*"

A.—Propeller.
B. Vertical Rudders.
C E. Moveable J int in Propeller Shaft.
F.—Steam Engine.
H.- Boiler.
M.—Orifice for Funnel.
N. Furnace Door.
K.—Conning Tower.
P.—Hot Water Cistern.
S.- Vertical Screws for Diving.
S .- Torpedo Tubes.
Q.—Radiator.
R.—Valve.
T .- Buoyancy Tank.

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Displacement . . 160 tons.
Coal . . . . . 8 „
Range without replenishing 900 miles.
I.H.P. 250
Speed 11 knots on surface, 5 knots submerged.
Armament, two torpedoes 14 ft. long, carried externally on the bow and arranged for mechanical discharge.
Two 1-in. Nordenfelt machine-guns.

The whole design was very similar to the first boat (Plate 13, Fig. 13). To improve the control in the vertical plane, the vertical screws for submerging were placed one forward and one aft, in the central line, not athwartships, as in the first boat; also the hot-water storage-tanks were differently arranged, as shown in the diagrams. These boats were sent out to Constantinople in sections. One of them was fully completed, and carried out a series of trials in the Golden Horn and Sea of Marmora. Great difficulty was experienced in obtaining a Turkish crew, and all the trials had to be carried out entirely by Mr. Nordenfelt's representatives* from England (Plates 12 and 13).

As a surface vessel and semi-submarine this Turkish boat was most successful, but the alteration already referred to, by placing the vertical screws in the fore and aft line, was not a successful departure, as the boat, when submerged, was most ticklish to handle in the vertical plane. The oscillations, the crew state, were very unpleasant, as the boat was practically never on an even keel for more than a few seconds at a time.

The ballast-tanks were not sufficiently subdivided; this allowed a large free surface of water to move about on any inclination the boat was given. The water in the boiler and hot-water storage-tank aggravated this tendency.

Once a torpedo was actually fired, with the result that the bow was thrown up as the torpedo left the tube. The water in the boilers and other tanks ran aft, and the submarine took a downward plunge, stern first, at an excessive inclination. Fortunately the operators kept their heads and managed to successfully bring the boat to the surface. On another occasion she was nearly swamped

* Captain Garrett and Captain P. W. D'Alton.

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by a steam-pinnace coming alongside without warning and sending the wash down the open conning-tower.

The boat was accepted by the Turkish Government, and the other boat was never even completed. Both are now rotting in a shed at the top of the Golden Horn, with probably very few of the original fittings intact.

About the time of this acceptance Mr. Nordenfelt became connected with the Barrow Shipbuilding Company, afterwards the Naval Construction and Armament Company, to which he sold his submarine inventions for further development. This resulted in a large boat being laid down in their shipyard at Barrow-in-Furness (Plate 14).

The dimensions of the Turkish boat were expanded to a

Length of . . .	125 ft.
Diameter . . .	12 „
Surface displacement .	160 tons.
Submerged displacement .	230 „
Minimum metacentric height	4 in.

The hull was constructed of plating $\frac{5}{16}$ in. in thickness and 1 in. over the turtle back, as a protection from small gun-fire. The structural strength was sufficient to stand a submergence of 100 ft. without collapsing. The machinery was manufactured by Messrs. Plenty and Sons, of Newbury, and designed to give 1000 I.H.P. with an estimated speed of 12 knots on the surface and a range of 1000 miles.

During the trials 1300 I.H.P. was actually developed and a speed of 14 knots * obtained over the measured mile in Stokes Bay. The submerged speed was 5 knots with a range of 20 miles.

The engines in this submarine were placed amidships and the same propelling system as in the previous boats was adopted, with the addition of various small improvements that had been suggested by actual experiment (Fig. 14).

This design was far more elaborate than the previous boats, but, owing to the unsatisfactory control in the vertical plane shown by former experience, the spindle-shaped hull was abandoned and a shape as shown in diagrams was adopted. The submerging propellers

* 14 knots was also obtained off Calshot Castle in May 1887. Captain D'Alton has kindly verified these figures.

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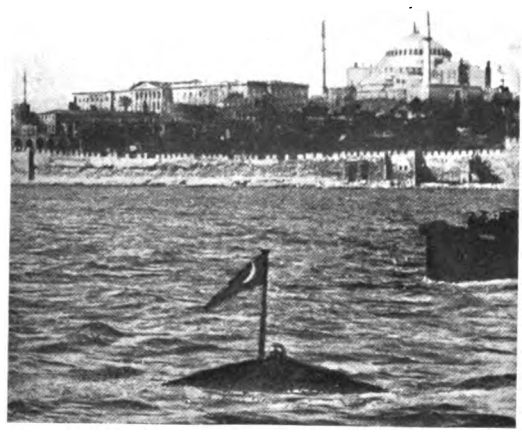

PLATE 12.—"*TURKISH NORDENFELT*" *RUNNING WITH CUPOLA OUT OF WATER IN GOLDEN HORN, CONSTANTINOPLE*, 1888.

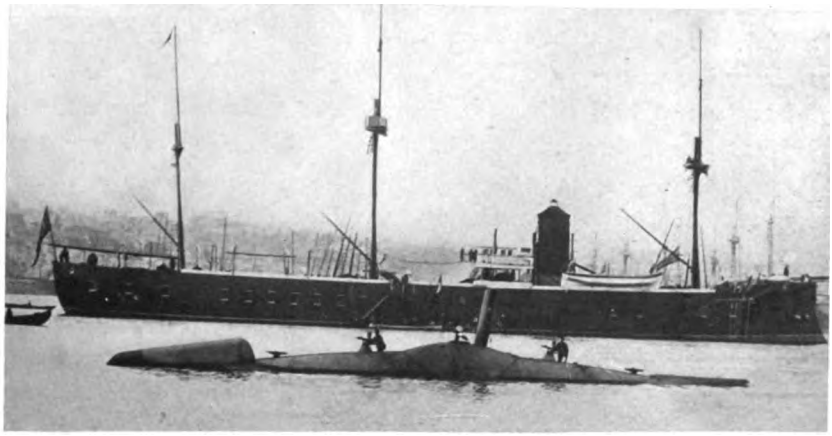

PLATE 13.—*THE "TURKISH NORDENFELT" AT CONSTANTINOPLE*, 1888.

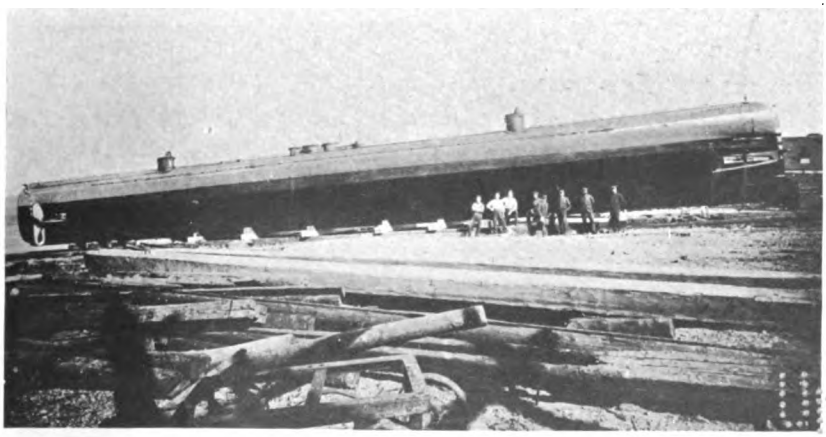

PLATE 14.—*THE "RUSSIAN NORDENFELT" ON THE STOCKS*, 1887.

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were again altered and placed one right forward and one aft. Two conning-towers were added, each 2 ft. in height and 2½ ft. in diameter, made of 1-in. steel. The captain usually worked the boat from the forward one, where he had the means for controlling the submerging propellers. In each conning-tower a stout glass dome was fitted; this enabled the captain and a look-out man to have an all-round view of the horizon.

To prepare for diving, the funnels were lowered, all openings sealed, and the glass domes closely screwed down, water ballast was then taken into the tanks and buoyancy reduced to 500 lbs. The vertical propellers at each end were revolved and the boat screwed under the surface as before. As no electrical energy was carried in any of Mr. Nordenfelt's boats, they were internally lighted by candles.

The boat was taken from Barrow to Southampton for trials, which were carried out mostly over the Mother-bank Shoal in the presence of a large number of officers from the Admiralty and War Office, also many foreign naval attachés and colonial representatives.

The first run was made on the surface in an awash condition, and the boat did 8 knots with the tide and 5 knots against it; in this condition of trim she was taken round H.M.S. "Invincible," * exciting much comment by her novel appearance.

On the surface, in light trim, a speed of 14 knots was recorded. In these manœuvres the submarine compared very favourably with the torpedo-boat carrying the naval officers, who were watching the trials closely. From a distance the Nordenfelt boat looked like a mere streak in the water, and when going at full speed the bow and stern wave completely hid her hull in the hollow.

No doubt this boat will be remembered by many, as she was in the 1887 Review, and was looked upon as one of the most interesting features of the display, attracting even more attention than the very fast "Turbina" of the 1897 Review. The improvements in the position of the vertical propellers, new form of hull, etc., did not eliminate the tendency to oscillate excessively, and again this design failed in longitudinal stability. † Too much free surface in the tanks caused great exaggeration of the slightest inclination, with the result

* Then anchored in Cowes Roads, Isle of Wight.

† See Chapter XVI, on Stability.

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that the boat frequently came in contact with the bottom on the Mother-bank Shoal during her preliminary trials.

Where this boat excelled was when running on the surface and awash. She was painted a dull grey neutral tint, and in the waters of the Solent the boat was extremely difficult to see, even when close to, for the target she offered was only $\frac{1}{3}$th that of a first-class torpedo-boat. When trimmed awash it was almost impossible to see the two small conning-towers and low portion of the hull for more than a few hundred yards; even then these would have offered a poor target for any Q.F. gun at that time in existence (Plate 16).

For the first time torpedoes were carried for discharge from internal tubes; the early boats had them external to the hull. Notwithstanding the disadvantages of the imperfect vertical control, Mr. Nordenfelt induced the representatives of the Russian Government to consider the purchase of this boat. They were quite satisfied with her performances, and undertook to accept the submarine should she do the same trials off Cronstadt in deep water. In making this condition they wisely remarked, "Any boat can do trials in shallow water which could not be repeated in deep water. Should she at any time show an undue tendency to hit the bottom," etc. The preliminary negotiations were settled and the submarine started under convoy for Russia.

During the passage everything went well until the coast of Jutland was reached, and then, unfortunately, the "Nordenfelt," whilst towing Captain Garrett's yacht the "Loadstar," ran on a sand-reef named the Horn (Blaavands Huk). This misfortune was caused through the officer of the watch mistaking the lights on the coast. When the submarine struck the reef the tide was ebbing, so nothing could be done until high-water, and even then all attempts to float the boat failed.

After many repeated efforts Captain Garrett reluctantly abandoned the submarine because the "Loadstar," from constant bumping on the reef, began to break up; this forced the crew to take to the boats and make the best of their way to Esbjerg, which was reached after some hours' hard pulling. A fortnight later a salvage steamer arrived at that port with the "Nordenfelt" in tow, and looking little the worse for her spell on the reef. The owners of the submarine argued that to them she was constructively a total wreck, as the Russian Government would not conclude the purchase after the boat had been bumping on the rocks.

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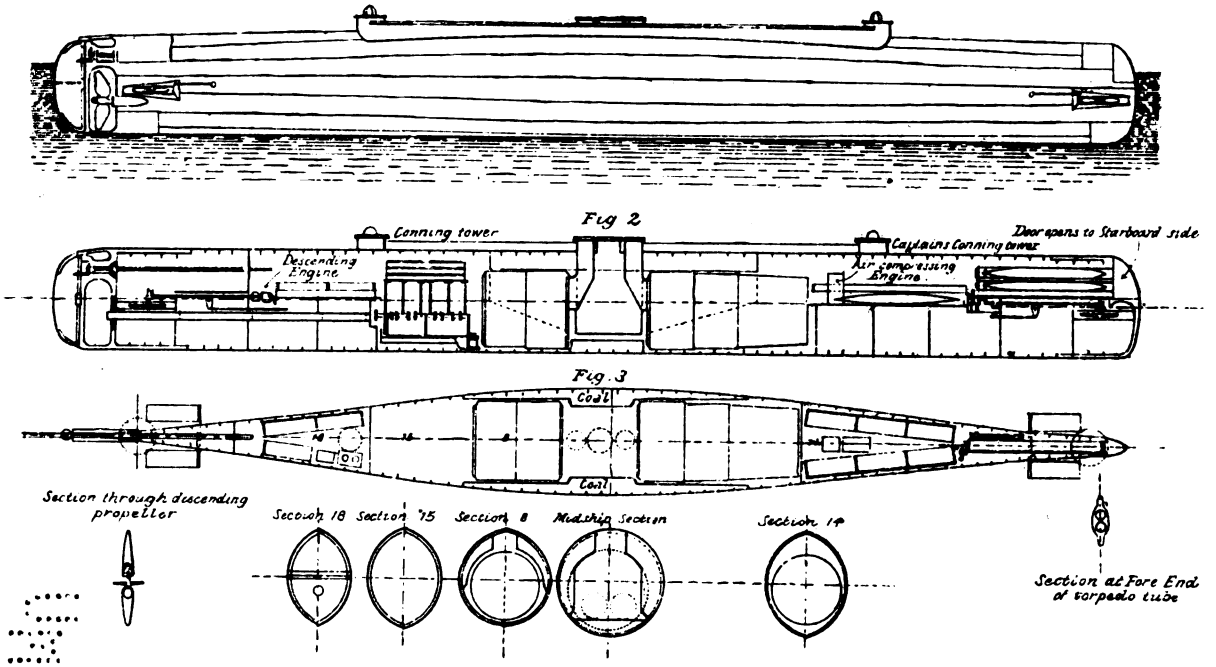

FIG 14.—*THE "RUSSIAN NORDENFELT."*

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After some dispute about payment of salvage fees, etc., the submarine was finally left on the salvage company's hands, and a few years later the hull was broken up to sell for scrap, as a purchaser could not be found for the boat intact. The insurance companies finally settled the matter by compensating the Naval Construction and Armament Company for all pecuniary loss in connection with this submarine.

Mr. Nordenfelt, in a lecture given at the Royal United Service Institution in 1886, with the late Lieut.-General Sir Andrew Clarke in the chair, in presence of the Duke of Edinburgh, Admiral Sir Cooper-Key, etc., gave a long description of his boats, and drew particular attention to several points, which I take the liberty of repeating. First, with regard to submerging the boat by mechanical means, the lecturer said:

"I feel confident that previous attempts have proved unsuccessful mainly because either they depended upon varying the displacement of the boat by taking in water to submerge her, and to regulate the depth at which they desired to operate, or they descended by steering downwards.

"My objection to the first-named method of descending by taking in water, and thus increasing the specific gravity of the boat, is that practically there is no difference of the specific gravity of water on the surface and at 50 ft. depth; thus, when the boat has lost its buoyancy at the surface, it has also no buoyancy at any given depth, and the risk is thus very great of suddenly descending beyond a safe depth.

"Further, by this method they relied upon some mechanical means for ascending by ejecting water. In case such mechanical means failed, the boat would be lost.

"Secondly, the horizontal position I have found to be a *sine qua non* for a submarine boat, I have therefore provided rudders, which I prefer to place in the bow of the boat,* and which, by the action of a plumb weight, are always held in the horizontal position, and therefore, should the boat from any cause tend to take a direction other than the horizontal, these rudders will immediately bring the boat back to the horizontal position."

Sir Cooper-Key offered, in the discussion that followed the lecture, a few remarks, in which he said:

* These were only applied to "Nordenfelt I."

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"I think the principles which Mr. Nordenfelt has adopted—in the first place in having his stored energy in such a simple medium as hot water, and in the second place in having the means of raising and lowering the boat by the mechanical power of vertical screws and bow rudders—are both sound and admirable. We have heard much nonsense talked about regulating the depth by the specific gravity of the boat when under water. If, however, she is made heavier than the water, down she goes to the bottom. If she is lighter than the water, she comes to the top. Without mechanical appliances there is no realiable means of keeping her at a fixed distance below the surface, or having it in your power to raise and lower the boat with regularity. I believe that this submarine boat has a great future, and than Mr. Nordenfelt has achieved a great success. As I have said, the question of speed is one to which a little more attention might be paid; and it must also be borne in mind that when you are going to fire a torpedo you must see the vessel you are going to fire at."

And in conclusion the chairman, Sir Andrew Clarke, made these few remarks:

"Your Royal Highness and gentlemen,—It is past the usual hour at which these meetings close, and even if I felt inclined I should not detain you by any remarks of mine. I had the opportunity of seeing this boat on the Swedish coast, and of being present at the trials. I have also had to report to the Government the result of these investigations, and, without saying whether that report was favourable or not, I will only say from the criticisms that have passed—especially from the distinguished naval officers who have addressed this meeting—that if my report has been a favourable one I have not erred in their opinion. I think the highest compliment which I can possibly imagine to Mr. Nordenfelt and to this invention was the criticism which we heard from the most distinguished scientific authority in the navy of the present day, I mean Sir Cooper-Key, who apparently entirely accepted the practicability, the security and safety of this vessel, and whose criticism was limited to the question of speed. I think that shows that evidently, as far as practicability of warfare is concerned, this submarine boat is pretty well accepted by the profession. The only other observation which occurs to me is this, I do not myself attach such very great importance to this invention as a powerful means of submarine defence in English waters. I believe we have a great deal to learn in this vessel with reference to over-

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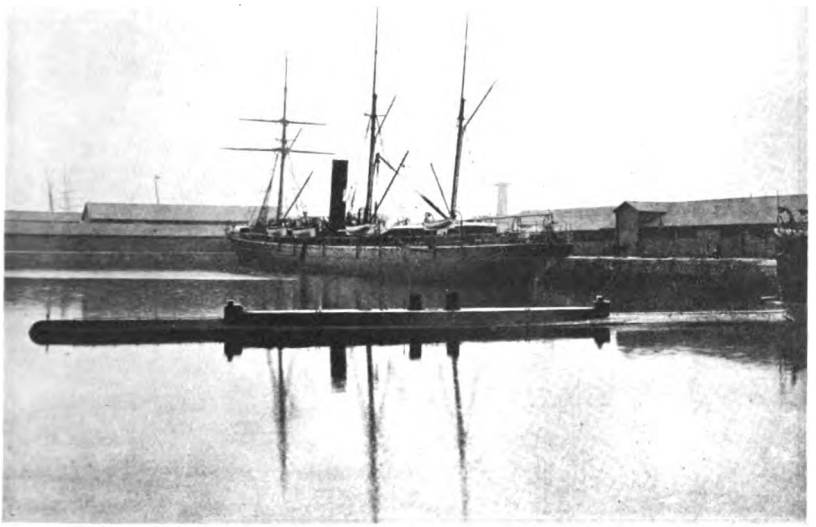

PLATE 15.—"*RUSSIAN NORDENFELT.*"
Prepare to dive, close all apertures, down funnels, &c., Southampton Docks, 1887.

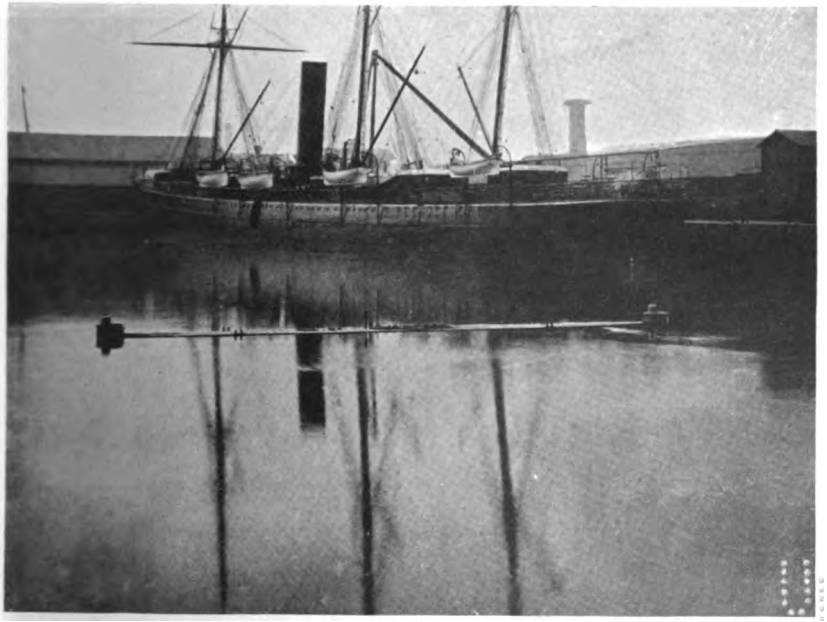

PLATE 16.—"*RUSSIAN NORDENFELT.*"
"Trimmed for diving," Southampton Docks, 1887.

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coming tidal currents and currents when submerged. In smooth, calm waters, where there is an absence of tide and current, I believe it is a very formidable machine, and although General Hardinge Steward alluded to the facility with which this vessel was seen in a glassy sea, I can only say that when there was the slightest ripple on the water at distances of 200, 300, and 400 yards, it was very difficult to distinguish. Therefore, as a craft not altogether wholly submerged, but just a boat awash for coast defence and also for the attack of ships at sea, and especially in heavy weather, when the fast torpedo-boat cannot act, I believe this vessel will be found of great practical and reliable service. I will not detain you longer, but will ask you to give me permission to convey our best thanks to Mr. Nordenfelt for his very interesting lecture."

It is now no secret that Sir Andrew Clarke strongly advocated the purchase of one of Mr. Nordenfelt's boats for systematic experiments, at a cost of £9000; he considered that this was the right weapon to develop for the protection of important strategic ports abroad, in preference to a large expenditure on land fortifications and corresponding increase of military personnel.

These opinions of twenty years ago, pressed very forcibly in official documents, have now begun to be generally recognised.

In summing up Mr. Nordenfelt's experiments we may say that the inventor was rather too optimistic. The actual results obtained entitled him to claim a fair amount of success; but in the published accounts these were distinctly overdrawn, mainly, it is believed, for commercial purposes, as Mr. Nordenfelt was not one to leave a stone unturned in bringing forward any invention he was interested in.

Had this type of submarine been taken up by our Government and systematically developed in a similar manner to that in which the Whitehead torpedo* was, no doubt an equally successful result would have been obtained by the torpedoists of that time.

* Chapter XXII.

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CHAPTER VIII.

SPANISH SUBMARINES.—1860.

SPAIN first began experimenting with submarines as early as 1860. It is recorded that an engineer named Narcisso Monturiol constructed a boat which he named the "El Ictineo." She was a copy of Bauer's boat and had a length of 17 metres with a beam of 3 metres.

Experiments were carried out at Barcelona and Alicante, during which a depth of 18 metres was reached; the crew of ten men on one occasion remained under water for five hours, an oxygen producer being used for these trials. The results appear to have been satisfactory, but apparently led to no definite results. Nearly thirty years later a young Spanish lieutenant, Isaac Peral, took the submarine question up and designed a boat (Plate 17, Fig. 15), which was laid down towards the end of 1887 and launched on September 8th of the following year.

Her dimensions were:

Length . .	70 ft.
Maximum beam	8½ „
Displacement .	80 tons.

The motive power was furnished by 420 accumulators, to drive two main motors of 30 E.H.P., coupled to two propellers, and three auxiliary motors of 5 E.H.P. for working the pumps to empty the water-ballast-tanks. One motor worked each vertical screw, as in the "Nordenfelt" design, for screwing the boat under water against a small reserve of buoyancy. Compressed air for blowing the tanks was carried in reservoirs. The armament consisted of one torpedo tube for discharging Schwartzkopf torpedoes.

On completion of the boat, Lieutenant Peral carried out many successful experiments; some modifications were made and further

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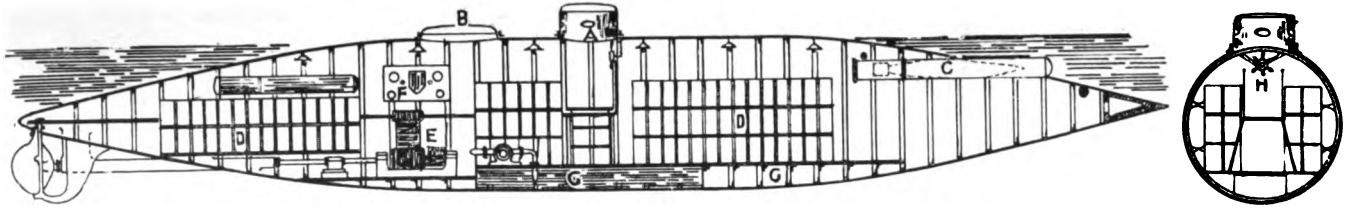

FIG. 15.—*PERAL'S SUBMARINE.*

A.—Conning Tower.
B.—Hatch.
C.—Torpedo Tube.
D.—Accumulators.
E.—Electric Motor.
F.—Switchboard.
G.—Water Ballast Tanks.
H.—Wheel for Working Vertical Rudders.

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trials were undertaken in the middle of 1890, during which the boat ran for 10 miles closed down, most of the time awash and occasionally dipped right under water. Such favourable results raised considerable enthusiasm in Spain, and Peral received the order of the second class of naval merit.

Continuing these experiments in the bay off the Arsenal of Carraca, he carried out evolutions awash with the conning-tower just showing, and in this condition there is no doubt that the boat was a great success. In day work against the "Cristobal Colon," a Spanish cruiser, the results were not quite so successful; but one night he actually placed his submarine within 10 metres of the ship without being discovered. After these manœuvres the Spanish Government fully recognised the capabilities of Peral's boat and gave the lieutenant a national gift of 500,000 francs with a title of nobility.

The faults of the boat, like those of the "Nordenfelt," were excessive oscillations when submerged. This naturally gave a faulty depth-line and showed there was insufficient control in the vertical plane.

If further designs had been undertaken no doubt a satisfactory boat could have been produced. Instead of which this seven days' wonder ceased to be of interest and all enthusiasm died out. The boat was then, metaphorically speaking, picked to pieces; all her bad points were exaggerated; and because the electric accumulators required renovating at a cost of few thousand pesetas, the Spanish authorities damned the boat and ordered an enquiry into the whole question of this submarine design. The proceedings of the Court were published at great length in the Spanish naval journals of that date, from the pages of which the following extracts have been taken.

"The Superior Court of the Navy, composed of Admiral-in-chief of the Fleet, assisted by those at the head of the administration, Artillery, Engineers, and the Assessor-general, held deliberation, and after full discussion, with all the facts and antecedents which could enlighten their opinion upon the decisive trials of the submarine 'Peral,' came to the following conclusions on the 27th September, 1890:

"'After all explanations and the fullest and most extensive discussions, the Superior Court of the Navy finds itself in agreement that the electric submergible torpedo-boat, invented and constructed by the lieutenant of the navy, Isaac Peral, does not fulfil the conditions which its author promised, the principal causes being due

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to his want of practice in the science of naval construction, and to the complex and difficult problems which enter into submarine navigation. Nevertheless, desiring to follow, as other cultured nations, the experiments upon the application of submersible torpedo-boats to the art of war, and utilise the very valuable material which to-day exists in the Arsenal of the Carraca; and also, taking into account the knowledge, patriotism, industry, zeal, and earnest desire which adorn Lieutenant Peral, as also the experience acquired by him, agreed that it considered the construction of a new submarine boat advisable, according to the plans which Lieutenant Peral may present, and under his direction; it being understood that said plans, the general project, and the execution of the works, must be examined, approved, and inspected by the authorities and centres to which it may regularly correspond, because it treats of a construction which does not need a special procedure.'"

Lieutenant Peral objected to these restrictions, and maintained that he was ready to present plans of a new submarine torpedo-boat of 120 tons displacement, reserving to himself liberty of action, not only to inspect and direct this new ship, but to furnish it with electrical apparatus (whose absolute application he reserved to himself), to designate the arsenal in which the construction was to take place, to choose the employés which had to carry it on, and later to name the crew. The Commission, after many regrettable arguments extending over a long period, decided not to accept Lieutenant Peral's propositions, because they did not fulfil the stipulated ends, which were to utilise in the new submarine the very valuable electrical plant of the old one; to reduce to a minimum the cost of what was still considered an experiment; nor did they consider it desirable to give the lieutenant such a free hand with the workmen of the arsenal as was enjoyed by him in the first construction. They finally condemned the lieutenant's arrogance as unseemly and contrary to the usual scientific man, who is generally modest and retiring.

The Commission then ordered the commander of the submarine torpedo-boat to deliver in the Arsenal of Carraca under inventory the accumulators, motors, pumps, and other effects and material of the vessel, and that note be taken of what parts of the actual submarine may be utilised in another, in order that, should the Government consider it advisable, they can proceed with a new construction in the form and under the conditions which may then be determined, and

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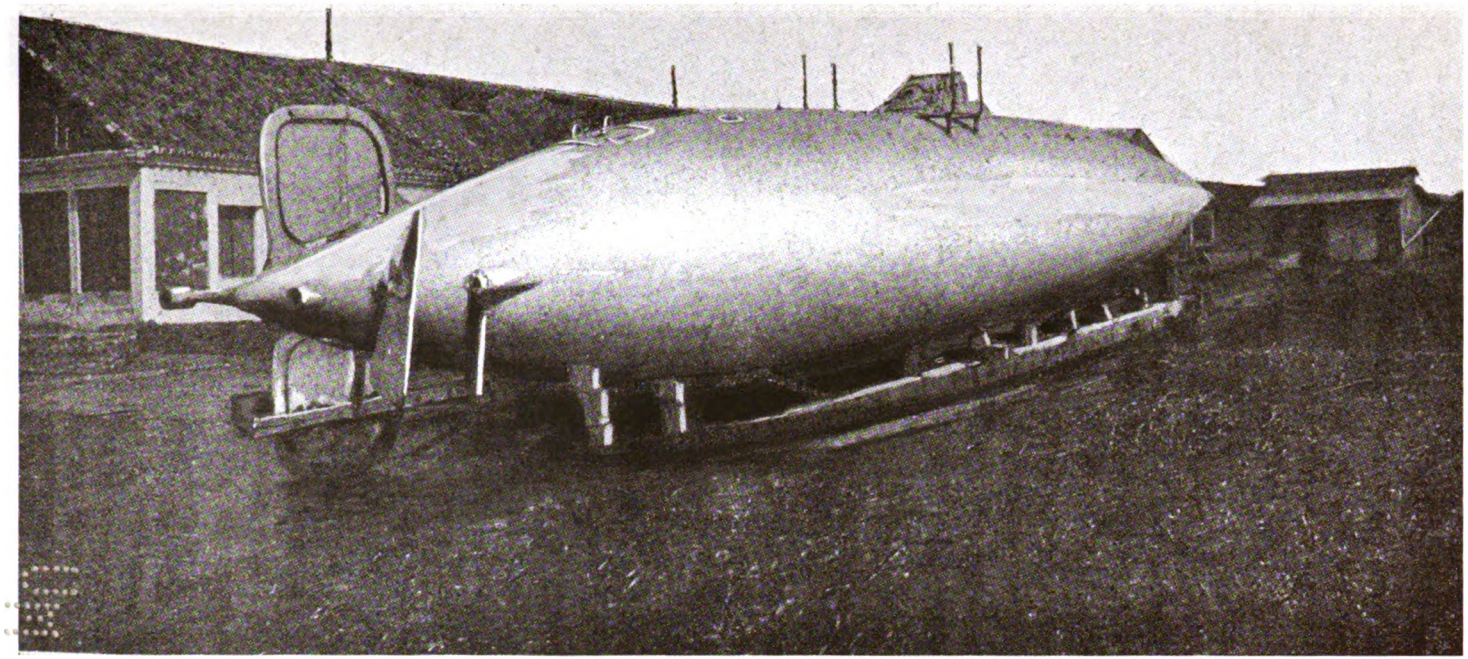

PLATE 17.—*SPANISH SUBMARINE "PERAL."*

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stated in their final resolution that they considered it advisable to continue the investigations of submarines as applied to the defence of harbours and coasts, and counsels that once the arsenal has received the existing material, a strict examination, study, and classification should be made of all Peral's gear in order to carry out afterwards what the Government shall decide regarding the new construction.

The council of Ministers, speaking on behalf of the King of Spain, upheld the findings of the Commission and considered that the actual state of the public exchequer was not the most propitious for new disbursements, which they presumed would be greater than those already incurred (without obtaining more than ideas, and no tangible result), they therefore decided not to trust Peral with the improvements in a new design, and thus was lost to Spain a grand opportunity of developing a defensive weapon so ably demonstrated by this capable and painstaking officer. With a little tact on both sides the results of years of patient work need not have been lost to his country. Had Cuba only been provided with a few of Peral's boats no American transports could have disembarked their troops and the blockading squadron would have had to keep at a more respectful distance. If Spain had only foreseen this, Cuba need never have been lost to her.

Admiral Dewey, U.S.N., says, *à propos* of boats of the "Holland" type submarine:

"If the Spaniards had had two such boats in Manila* I should have been unable to hold the bay with the squadron I had. The moral effect—to my mind—is infinitely superior to mines or torpedoes, or anything of the kind. With these craft moving under water, it would wear people out. With two of these at Galveston all the navies of the world could not blockade the place."

One cannot help sympathising with Lieutenant Peral in his efforts to get his country to take up the submarine boat seriously and develop it for defensive purposes. Progress, however, should never be sacrificed on the altar of self-aggrandisement. Pioneers would do well to cultivate a loftier, higher, and nobler aim. Fresh nourishment in the form of new ideas, with free and unbiassed criticism, should be welcomed with open arms. Fortunately no one person can hinder or advance more than a limited amount such a science as submarine navigation, nor has the individual any right to assume

* Spanish-American war, 1898.

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that he is indispensable in the development of a weapon that has been considerably advanced by the pioneers of earlier days.

The greatest failures in this world—to borrow a quotation from Mr. Morley—are those who expect more from life in the world than life in the world is capable of giving.

The above applies to so many pioneers who, after doing really good work, finally hamper progress by refusing to accept the opinions of those who have a mental capacity equal, if not superior, to their own.

As several people in this country are now naturally more concerned than hitherto in the well-being and protection of Spain from outside encroachments that might arise from complications on account of Morocco, or from any other cause, it will be welcome news to know that such up-to-date weapons as modern submarines are shortly to be added to her navy; for we notice that during his recent visit to England,* King Alfonso showed the keenest interest in this type of war-vessel, and expressed the hope that within a year or two Spain would have a submarine flotilla for the defence of her Mediterranean coast-line.

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* Winter of 1906.

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CHAPTER IX.

THE "NAUTILUS" OF ASH AND CAMPBELL, AND WADDINGTON'S SUBMARINE.

"NAUTILUS"—1885.

IN 1885 two English inventors, Messrs. Ash and Campbell, came forward with designs for a new "Nautilus," copying the name given by Fulton to his submarine.

This boat was constructed by Messrs. E. Wolseley and C. E. Lyon; a brief description of the design is interesting. She was given a length of 60 ft., with a maximum diameter of 8 ft., the hull had a circular section tapering towards the bow and stern, as shown in diagram (Fig. 16). A conning-tower and superstructure arose in the centre of the boat, and the former had the usual hinged lid as a means of entry. The superstructure was 20 ft. in length and 2·2 ft. high, with thick glass scuttles fitted all round for observation purposes; the top of this formed a convenient platform for the crew to work upon when in surface trim. The hull was built of $\frac{5}{16}$-in. Siemens-Marten steel-plates rolled to the necessary shape and riveted to frames placed 21 inches apart. The boat was designed to stand a maximum depth of 50 ft. and had a submerged displacement of 50 tons.

In the interior amidships 104 electric accumulators, divided into two batteries of fifty-two each, constructed on the Elwell-Parker system, were built in, and these stored electrical energy for working two motors of the Edison-Hopkinson type, which turned two propellers at 750 revolutions per minute. The boat was supposed to have a speed of 8 knots, and since the accumulators were designed to last ten hours, the range of action was 80 miles. The maximum current available was 180 ampères at a pressure of 104 volts.

The boat was divided into four compartments, one of which was fitted as a diving-chamber to allow a man to go out to fix a mine. The principles of immersion were based on submersion and immersion

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by change of volume. By diminishing the volume of displacement, weight remaining constant, the weight of the boat became more than the weight of the volume of water displaced. The boat sank to the required depth, and the operator then tried to establish equilibrium by making the weight of the volume of water displaced equal to the weight of the boat.

To arrange for the practical working of this principle four cylinders were built on each side with pistons moving in glands through the side of the boat. On the inner side of the piston was a screwed rod, and all the pistons on one side were geared to those on their respective sides and were moved by the large motors when it was required to push them in or out. Water ballast was taken in until the superstructure just remained out of water; the pistons were drawn in until the boat began to attain downward momentum, then they were pushed out to check this and establish equilibrium. A horizontal rudder was used to control the boat in the vertical plane, and the usual vertical rudder was fitted for guidance in the direction required. The crew, numbering six, were stationed in the central part of the boat. The air supply was sufficient to last for two hours, being augmented by compressed air stored in cylinders if required. She was supposed to carry two Whitehead torpedoes in frames on either side of the superstructure, but no trace of armament trials can be found; it is even doubtful if they ever reached this stage.

When fully equipped her freeboard was 10 in. Water ballast was carried for pumping out should any hitch arise with the pistons, also a heavy keel was fitted which could be slipped on emergency.

This submarine was going to do great wonders as a "Nautilus" having all the most modern appliances introduced into her. In 1888, during some trials in the deep-water dock, Tilbury, with a few distinguished persons on board, the boat was submerged and stayed for a long time on the bottom of the dock before she could be raised. It happened that when the pistons were withdrawn the boat suddenly sank in the mud, and no amount of pushing the pistons out, discharging water ballast, could make her rise. A fortunate inspiration suggested itself to one of the occupants. That was to work the crew backwards and forwards to free the boat from the suction of the mud. This, after an anxious time of it, proved successful, and the boat's own buoyancy brought her to the surface, much to the relief of everybody concerned.

This method of submergence, theoretically, is perfect, but in

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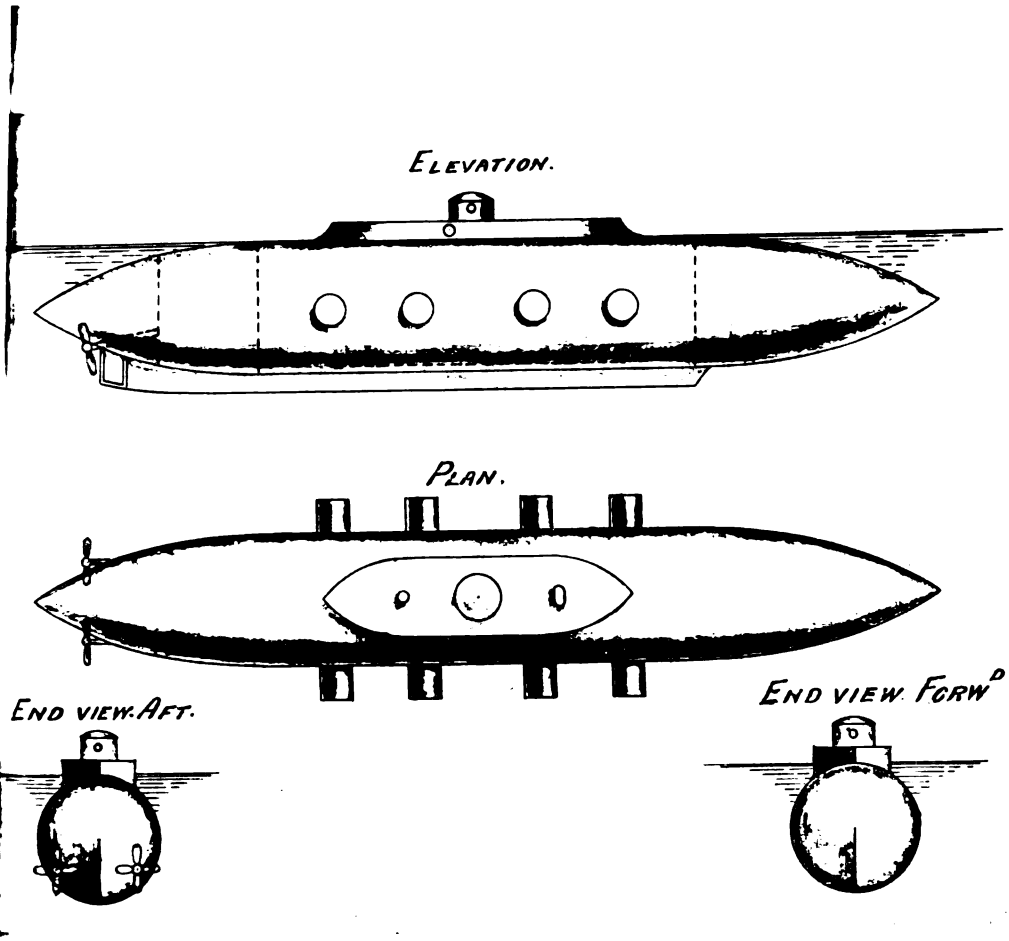

FIG. 16.—*THE "NAUTILUS" OF ASH AND CAMPBELL, SHEWING THE PISTONS FOR INCREASING OR DECREASING VOLUME OF DISPLACEMENT.*

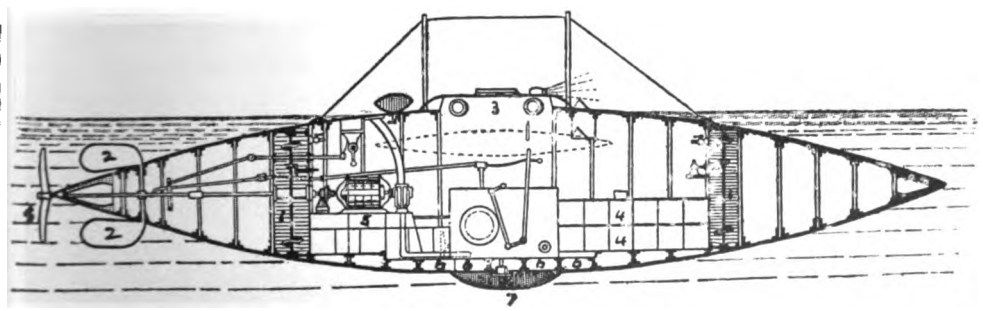

FIG. 17.—*"WADDINGTON'S" SUBMARINE.*

1.—Vertical Screws for Diving.
2.—Vertical Rudders.
3.—Conning Tower.
4.—Electrical Accumulators.
5.—Electric Motor.
6.—Water Ballast Tanks.
7.—Safety Weight.
8.—Propeller.

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practice quite another thing; the difficulty of working the pistons accurately enough so as to obtain a balance is next door to impossible. The trials were never completed, the boat being a perfect failure.

WADDINGTON—1886.

At Seacombe, near Liverpool, a large number of useful experiments were carried out in 1886 by a Mr. Waddington.

He designed and built a submarine boat, under the name of "Porpoise," having a length of 37 ft. with a maximum beam of 6½ feet. The hull was circular at the midship section and tapered gradually towards the bow and stern (Fig. 17), with interior divided, as shown in diagram, into three compartments. The foremost one contained the compressed air supply, then came the foremost diving propeller tube. The midship compartment contained the tanks for taking in water ballast, the battery of electric accumulators, and the electric motor.

Abaft the after diving propeller tube was the compartment through which the main shaft and rods for working the rudders passed. Small electric motors were used to drive the vertical screws, two of which were mounted on each shaft fixed in the tunnels running right through the boat at each end. Electrical energy was furnished from forty-five of the Electric Co. accumulators to work a motor designed for 66 ampères at a pressure of 90 volts; the E.H.P. was 7·96 and the efficiency of the motor is recorded as being 81 per cent.

Mr. Waddington was a scientific man and carried out his experiments systematically. His method of controlling the boat in the vertical plane was similar to that adopted by Mr. Nordenfelt; the boat was screwed down against a reserve of buoyancy, horizontal rudders were provided to assist in keeping the boat at an even depth-line, and the usual vertical rudder controlled the direction in the horizontal plane. The boat was designed to be carried on board a war-vessel, but, as the battery of electric accumulators was so heavy, no tackles in any ship afloat could have conveniently hoisted her in; the design was therefore not repeated; but at that time Mr. Waddington's boat was quite a success. Air experiments were carried out and sufficient compressed air was carried to last the crew of two men six hours.

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CHAPTER X.

FRENCH SUBMARINES.

PART I.

In 1858 a Captain Bourgois in the French Navy thought a submarine boat propelled by compressed air would meet all the requirements of coast defence and, in able hands, become an effective weapon for that purpose. He therefore sent in designs of an air-propelled under-water vessel capable of carrying a torpedo fixed to the end of a spar. The explosive charge was intended to act below the side armour of an enemy's ship, and could be fired from inside the boat. In the following year the Minister of Marine, after carefully considering these plans, invited engineers to build a boat on the lines suggested by Captain Bourgois. Amongst the detailed plans sent in were those by M. Brun; these were considered favourable, and resulted in the construction of a boat which was launched, under the name of "Le Plongeur," from a yard at Rochefort in April 1863.

The hull was constructed of iron plates, riveted to supporting frames, fastened to a heavy vertical keel made of the same material; the plates butting the vertical keel were about $\frac{8}{16}$ in. in thickness. This keel extended right forward and formed a support for the torpedo spar, which was made 10 ft. in length with a diameter of 1 ft. (Plate 18, Fig. 18).

Two bilge keels were fitted on either side of the hull to prevent rolling when running awash. The upper deck aft was nearly flat, like a torpedo-boat, and carried side rails, etc.

The dimensions were approximately as follows:—

Length	140 ft.
Depth	10 „
Top of conning-tower to keel	14 „
Maximum beam . .	20 „
Displacement . . .	420 tons.

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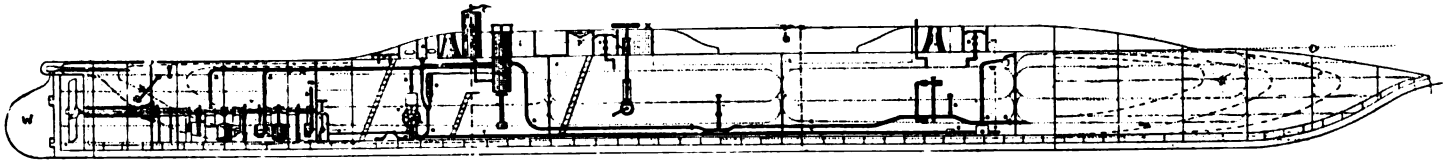

FIG. 18.—"*LE PLONGEUR*."

a.—Compressed Air Service.
b. - Stowing Position of Detachable Boat.
b'. Diving Rudder.
c. - Conning Tower.
d. - Compensating Cylinder.
e. - Water Service.
h.—Horizontal Rudder.
k. Reservoirs of Compressed Air.
p.p'.—Hatches.
x.—Vertical Screw.
s.s'.—Air Escape Valves.
w'.- Compressed Air Pumps

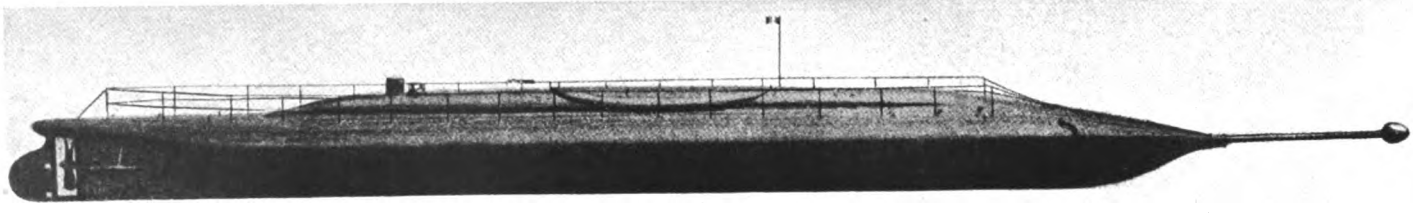

PLATE 18.—"*LE PLONGEUR*."

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In a hollow part of the hull, abaft the position of the foremost air-reservoirs, a safety boat was carried, 25 by 6 by 3½ ft., fitted with air-boxes at each end to make it unsinkable, and was capable of holding a dozen men; screw-bolts held the boat in position, and to prevent any leakage when under water a slight pressure of air was allowed into the interior of the submarine; this was kept greater than the pressure due to the head of water outside, to prevent water trickling down the securing bolts of the detachable boat. Several experiments were made ~~increasing this boat~~, and are reported to have been quite successful.

The motive power was compressed air, stored in reservoirs made of sheet steel, 0·3 in. thick, these were twenty-three in number, and could be charged to 180 lbs. per square inch, their capacity being 147 cubic metres. Even at this low pressure of storage it was difficult to prevent great leakage of air—so much so that, when coming to the surface and throwing open the hatches, a dense fog prevailed. This is noticeable in any modern submarine if the joints of the air service leak, and is due to the sudden expansion of the air under pressure; at first this is rather alarming to a novice and gives an uneasy feeling in the drums of the ears immediately the pressure is released. The fitting of an escape-valve in the hull of a modern boat gets rid of the excess of air pressure to a large extent.

The interior of the hull was divided into water-tight compartments by five transverse and two longitudinal bulkheads, the two end and wing compartments were used as water-ballast-tanks for submerging. The air service was arranged for blowing out the tanks, but as these leaked badly, a considerable pressure had to be applied, and a large quantity of air found its way into the boat through the defective caulking of the angle-bars, etc.

This boat was designed on the equality of weight and submerged displacement principle. Under the centre compartment were suspended old shot, which could be dropped as emergency weights. These, with the ballast-tanks full (30 tons), just brought the boat to the awash position, with conning-tower only out of the water.

Two regulating cylinders were fitted, one before the conning-tower and one abaft, for making final adjustments of weight to establish equilibrium by means of a piston working in the cylinders.

Experiments were carried out between Rochefort and Charente, and the boat on one occasion reached a speed of 5 knots when running

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on the surface. Submerged trials were undertaken in a basin at Rochefort. To render these tests thoroughly safe, a pipe of large diameter was led from the boat to the surface of the water by which the crew could escape if necessary. The basin was about 20 ft. deep. During the first experiment an alarming incident occurred, as one of the scuttle glasses broke and let a large quantity of water into the boat. The onlookers hastily emptied the basin below the level of the damaged scuttle, and, beyond giving the crew a scare, little harm was done.

During the autumn of 1863 deep-sea trials were attempted, but great difficulty was experienced in controlling the boat in the vertical plane. The controlling cylinders were much too slow for their work, and the horizontal rudders were not powerful enough, consequently the boat, on more than one occasion, touched bottom, as she was always either up or down. The diagram (Fig. 18) shows the horizontal and vertical rudders for control in the vertical and horizontal planes respectively. As the vertical control was inadequate, a propeller was fitted in the middle of the boat at x to assist the horizontal rudders, but this only improved matters a little. The final results were not satisfactory, as no even depth-line could be maintained. Undoubtedly "Le Plongeur" was a considerable advance in submarine-boat construction, as close inspection of the model shows a very neat craft.

No other boats of this type were attempted, as the offensive power was so poor. Had the locomotive torpedo been in existence in those days no doubt other designs would have been forthcoming; but the results to be obtained by the ram or spar torpedo did not justify further development, and "Le Plongeur," after contributing her share in the evolution of submarine navigation, fell from the lofty pedestal of a scientific calling to more humble services, as she was afterwards turned into a common water-tank.

During the Paris Exhibition of 1867 two models of this boat were exhibited and attracted a large amount of attention; they are now in Room XVI, Musée de Marine, of the Louvre, Paris. The diagram shown was verified from sketches and notes made recently, under considerable difficulty, in the Museum, due to the attention of the attendants. The author's scrutiny being considered too close, he was followed about the building and regarded evidently with much suspicion, and finally ended in an attendant standing on each side of him as he examined an old 16-in. Whitehead torpedo.

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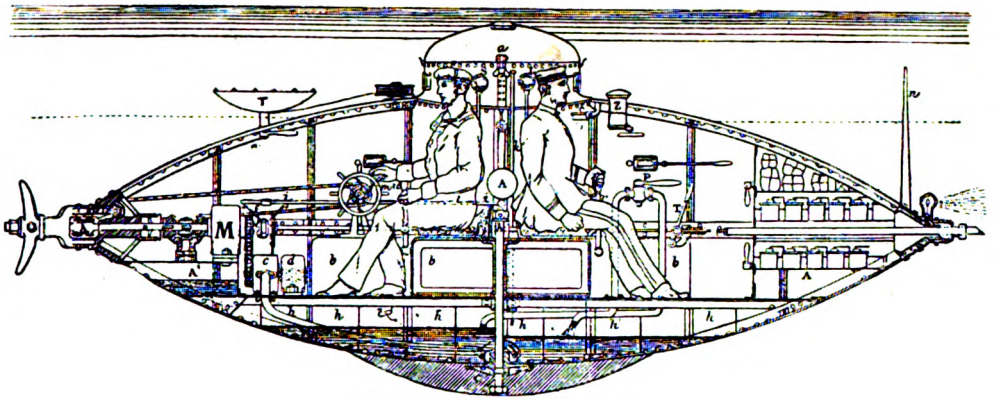

FIG. 19.—"*GOUBET I.*"

A A' (A).—Trimming Tank System.
a.—Conning Tower.
b.—Compressed Air Reservoirs.
c d.—Pumps.
h h.—Water Ballast Tanks.
i.—Electric Accumulators.
m.—Wheel for moving Propeller to Port or Starboard.
M.—Electric Motor.
P.—Water Ballast Control Valve.
T.—Torpedo for fixing to Hull of a Ship.
o.—Propeller.
x.—Safety Weight.
n.—Submerging Batten.

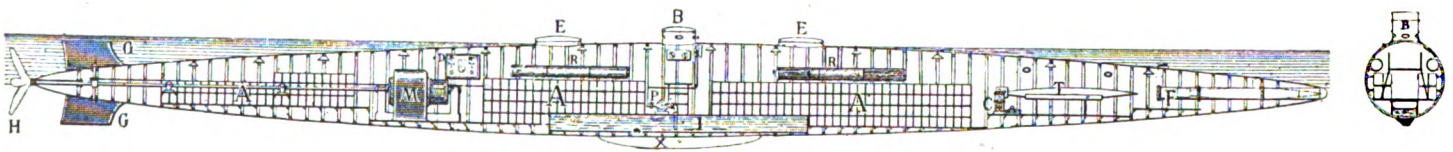

FIG. 20.—"*GUSTAVE ZEDE.*"

A, A.—Electric Accumulators.
B.—Conning Tower.
C.—Electrically Driven Air Compressor.
D.—Switch Board.
E.—Water-Tight Hatches.
F.—Torpedo Tube.
G.—Vertical Rudders.
H.—Propeller.
M.—Electric Motor.
P.—Electric Motor Pump.
R.—Compressed Air Reservoirs.
T.—Torpedo.
I.—Water Ballast Tank.
X.—Emergency Weight.

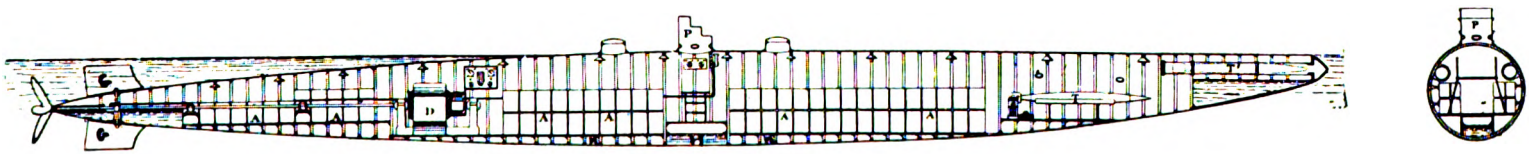

FIG. 21.—"*MORSE.*"

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The French Admiralty are unlikely ever to repeat the mistake that was made in turning the cold shoulder on Mr. Fulton; since that time they have always had a strong leaning towards torpedo warfare in its various branches. They are not and never have been so conservative as Whitehall in regard to new ideas. At the present time we find them several years in advance of any other nation in modern submarine-boat construction; but this is not remarkable, since France has led Europe in naval designs for many generations. In the old maritime wars her ships were nearly always better than ours, though perhaps not quite so well handled. She was the first nation to armour ships, introduce breech-loading guns, and latterly her successes with the Belleville and Niclausse boilers are too well known to need any comment in this chapter.

Starting with small submarines of 30 tons, the French designers have now reached boats of 800 tons. This advance has been due to systematic experiment, a glimpse into the various stages of which is instructive.

During the time Mr. Nordenfelt was carrying out experiments with his boats in England a smaller submarine received a considerable amount of attention in France. This boat was constructed from the designs of M. Claude Goubet, a civil engineer, and bore his name, being called "Goubet I."

Her dimensions were approximately:

Length 16½ ft.
Diameter at largest transverse frame, 5 ft. 9 in.
Weight 11 tons.
The armament consisted of two small locomotive torpedoes carried in collars on the sides of the boat externally.
Speed on surface, 4 to 5 knots.
Speed submerged, 3 knots.

The idea of building a boat of such a small size was that she could be hoisted on board a battleship and play the part of an invisible second-class torpedo-boat (Fig 19).

The "Goubet" belongs to the class that have no reserve of buoyancy * when running under water. Submergence was performed in the usual manner by admitting water ballast into tanks to bring the boat into an awash condition; then, by the addition of a

* See Chapter XVI, on Stability.

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further quantity, all reserve of buoyancy was destroyed. Her total weight in this condition exactly equalled the weight of the volume of water displaced. This, as we have before remarked, is unsatisfactory, as a little more one way or the other causes an erratic depth-line when in motion which even powerful rudders cannot quite overcome. The hull was made of bronze, pointed at both ends, being circular in form amidships. The conning-tower was fitted with port-holes, the hatch being made water-tight by means of an india-rubber joint, and the two operators could sit back to back on the top of compressed-air reservoirs, as shown in diagram (Fig. 19).

Through the conning-tower hatch a small periscope enabled the captain of the boat to see objects on the surface when his vessel was in a submerged condition. The motive power consisted of a battery made up of Laurent-Cely accumulators. This furnished the energy for driving the electric motor that was coupled direct to the propeller shaft. Off this shaft arrangements were made for throwing in a clutch for driving a pump to eject the water ballast. To remove the vitiated air, a pump worked by an endless chain could be used; also a bilge pump might be worked in a similar manner. The volume of air in the boat being small, air tubes containing oxygen under pressure were carried; this provision was found to be quite successful, and permitted the crew to stay for a considerable time under water without any ill effects. Some novel features were introduced in M. Goubet's design, the most important being the combination of rudder and propeller by a Goubet joint. This is sometimes referred to as a Drzewiecki joint; it is doubtful which of these two engineers first placed this system in a small submarine boat.

Out of a circular hole in the bows of the boat a steel bar could be run out to a distance of 3 metres,* and to this was attached scissors for use in cutting ships' torpedo nets. This idea was ingenious but not practical, as it is a matter of some difficulty to sever a grommet of a torpedo net with a cold chisel and hammer; to cut several grommets by the method proposed would have been a laborious undertaking. To prevent an enemy discovering the approach of the boat by the whirring noise of the motor, the designer had a couple of small oars fitted to allow of slight movements independent of the propeller.

* About 10 ft.

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The great difficulty M. Goubet had to contend with was to preserve the longitudinal stability of his boat, and to do this he employed the following system.

At each end of the vessel was a large circular water-tank, connected together by a stout pipe, in the centre of which rose a pear-shaped dome containing a pendulum, a rotary pump, and pipes connecting the two tanks. When the submarine showed a tendency to rise to the surface or to dive to the bottom, the pendulum swung forward (marking the extent of the deviation on a dial above the dome), and in so doing formed a connection between the motor and the accumulators; the motor then commenced to work the rotary pump from the higher tank to the lower until the boat was brought to a level position again. Control in the vertical plane by this method was not successful as the boat always had an undue tendency to suddenly dive. This fault did not, however, prevent her from being purchased by Brazil for the sum of £10,000.

An improved "Goubet," of slightly larger dimensions, was then built to the order of Admiral Aube, Minister of Marine (Plate 19). The construction was commenced at Cherbourg, in September 1886, the launch taking place early in 1889.

The "Goubet II" was

26 ft. in length,
6 ft. maximum diameter,

and, as in the first boat, bronze was used for the hull.

The motive power was provided from twenty-four Laurent-Cely accumulators, which furnished energy to a Siemens motor of the tramway type, 190 kilogrammes in weight, this took 9 ampères at a pressure of 48 volts.

Considerable interest was taken in a series of trials conducted in the docks at Cherbourg; one submerged run lasted forty minutes and was witnessed by a large number of naval and military officers, also by hundreds of spectators.

Flag buoys were laid down, some floating and some submerged; the boat was manœuvred in and out among the surface buoys and then cut the moorings of the submerged buoys, which, coming up to the surface with a bob, indicated the whereabouts of the unseen boat. A programme mine was exploded, telegrams sent to those inside the boat by means of glass balls, etc. These evolutions

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lasted for two and a half hours and, on the whole, were very fairly successful, except for the control of the depth-line, which left something to be desired.

It is recorded in various foreign publications that two of Goubet's men, in May 1889, stayed under water for eight hours. This was considered a great feat at the time. The crew suffered no inconvenience, except extreme boredom and much irritation at constant calls on the telephone, by which the boat was connected to the shore; the only message they cared two straws about was "Courage: only a quarter of an hour more!" Submarine workers in the present day are rather pleased to come up after a twelve hours' spell under water in boats many times the size of the little "Goubet," and fitted with all modern appliances, so we cannot help admiring the inventor's faithful assistants for submitting to so long an ordeal. Towards the close of her many trials the "Goubet II" on one occasion got into some difficulties during a submerged run and sank to the bottom, the emergency weight had to be resorted to, and it took ten minutes to unscrew the rusty bolts before the keel could be dropped and the boat brought to the surface. If she had not been provided with this means of increasing her buoyancy perhaps a reappearance on the surface might not have been a matter of minutes. From the many experiments made with this boat much reliable data was obtained in submarine work, but the system employed for submerging and control in the vertical plane was unsatisfactory; this made it extremely difficult to keep the boat on any alignment for discharging torpedoes, and when one was actually fired the boat's behaviour was more erratic still. In spite of many attempts to introduce improvements, by the insertion of two extra frames, etc., the boat did not fulfil the requirements of the French Government and therefore could not be accepted.

The "Goubet II" was eventually sold for a few thousand francs to an enterprising caterer of public amusements, who now runs her for passenger trips on Lake Geneva.

The patents of the "Goubet" submarine were sold to an English company, comprising an admiral and other ex-naval officers, who became interested in sub-aqueous enterprise, under the title of the "British Submarine Boat Company."

The boats were to have been constructed in the South of England to the plans that were carefully drawn out, but so far would-be

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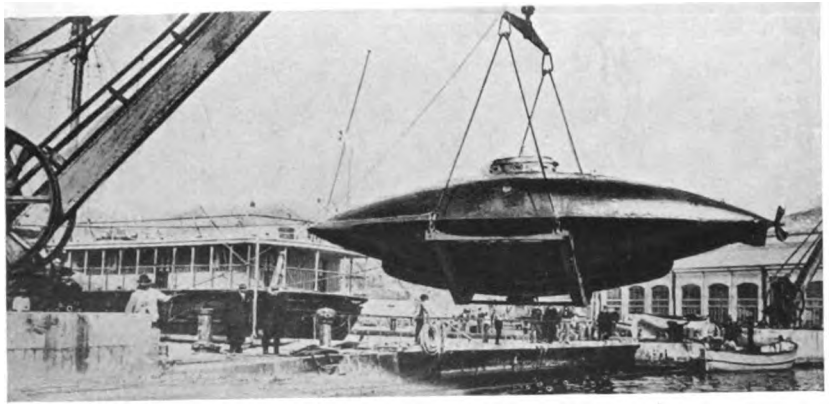

PLATE 19.—"*GOUBET II.*"

PLATE 20.—"*GYMNOTE.*"

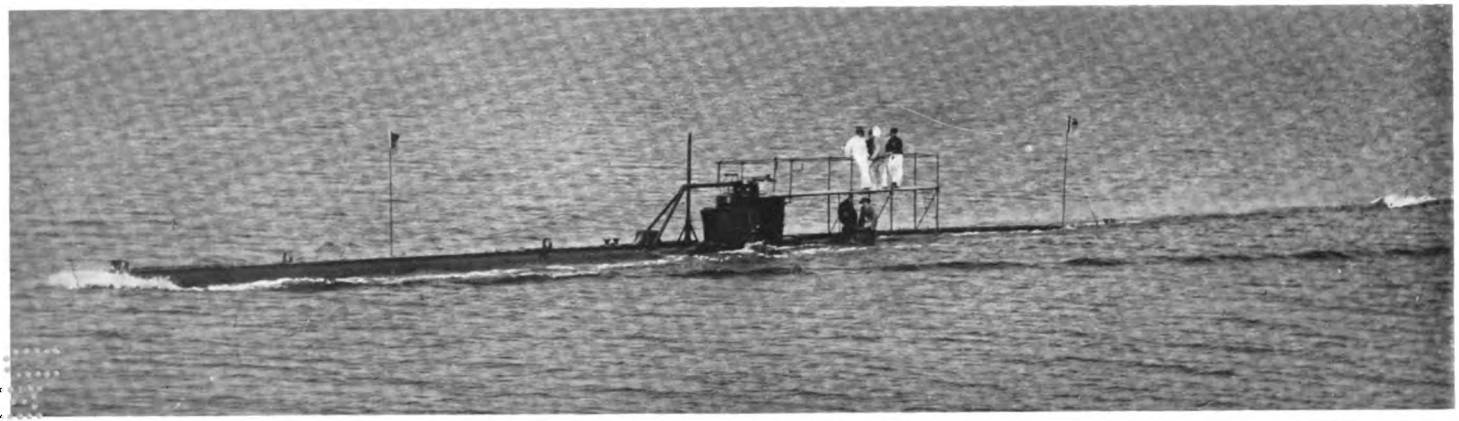

PLATE 21.—"*GUSTAVE ZEDE*" *RUNNING AT FULL SPEED.*

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purchasers, of the South American Republic order, have failed to put in an appearance, and the Company are still waiting for them to do so before making a start.

These boats were to have been supervised during construction by the designer, but unfortunately he was not spared to bring his inventive powers into greater prominence. For years M. Claude Goubet toiled incessantly, hoping one day the French Government would take up his boats. The rejection of "Goubet II" was a bitter blow, and affected his health considerably. Had he lived a little longer, no doubt fame would have reached him, as at the present time it is believed the French Government are interested in the construction of a small boat named "Goubet III."*

Most of the press obituary comments describe M. Goubet's career as having been wasted. This is characteristic of the manner in which a skilful inventor is alluded to when he finishes a life's devotion to science.

M. Goubet's was not a wasted career; granted perhaps that he made a little or no money, yet his name stands prominently out as one of the most ardent workers in a great attempt to conquer the laws of Nature. His results, even though of a negative nature, give many ideas which enable inventors to strike out in other directions and show us by their very faults how much not to follow.

We pay this great French engineer a tribute in saying that his life's-work forms one of the principal stepping-stones in the evolution of the submarine, as nobody will dispute that M. Goubet undoubtedly gave an enormous impetus to other workers in their efforts to invent a boat that would fulfil all the conditions required by those Governments who were interested in adding these weapons to their navies.

"Gymnote"—1886.

The impetus given to sub-surface construction by M. Goubet's boat led the celebrated French engineer, M. Dupuy de Lôme, to work out the designs of a submarine, but unfortunately he died before his boat could be laid down. Some time elapsed, then M. Zédé, a retired naval engineer, took up the former's ideas and modernised the plans. The designs were submitted to the Minister of Marine,

* Page 101.

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Admiral Aube, who had already taken some interest in the "Goubet" submarine, as he foresaw the great possibilities of these boats, if developed, being utilised for coast protection, and determined to assist the inventors in furthering their ideas. This decision and its consequences has provoked the greatest hostility from the old school of French naval officers, which feeling even exists at the present time. By the admiral's foresight France has been placed many years ahead of other nations, who then held aloof from this valuable submarine experimental work. After very careful perusal of the plans of M. Zédé, Admiral Aube finally ordered the construction of the first real modern submarine for the French Government, the work being confided to the Société des Forges et Chantiers de la Méditerranée. M. Zédé was a director of this company, and therefore was able to give personal attention to the minutest detail during the boat's construction, being in this ably assisted by M. Romazzotti a naval engineer.

The hull of the "Gymnote" was made of sheet steel rolled to fit the circular ribs of the spindle-shaped design, the frames being placed about 20 inches apart, and she was given the following dimensions:

Length . . .	59 ft. 10 in.
Diameter (amidships)	5 „ 10 „
Displacement . .	31 tons.

At first a telescopic conning-tower of tarred canvas fixed on steel springs was used, but this was exceedingly difficult to keep watertight. The idea was to lower the conning-tower when submerged and so prevent the speed of the boat being retarded. However various officers in command of the boat strongly condemned the device, as it had led to some awkward predicaments through excessive leakage; it was therefore removed and replaced by a solid one, with glass scuttles for observation purposes (Plate 20).

The buoyancy was decreased by admitting water into tanks in the usual manner, and compressed air was used for discharging this water ballast, an electric motor rotary pump served as an alternative, and in addition hand bilge pumps were fitted. The compass gave unsatisfactory results at first as the magnetic field was excessive, being due to the proximity of the electric wires leading from the batteries to the motor; a compass worked by a

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gyroscope was tried, but without much success. The magnetic field is now electrically compensated for, which gives better results.

The 55 E.H.P. motor was built from the designs of a naval officer; this gave a speed of 6·5 knots on the surface, but, after some experience, it was found too light for its work and had to be replaced by a more efficient type. The battery was made up of 564 accumulators, the whole having a weight of 987 kilogrammes.* The accumulators could be grouped together in four different ways by means of a grouping-switch.

Slow speed, 12 in. parallel and 47 in series.
Half speed, 6 in. parallel and 94 in series.
Three-quarter speed, 4 in. parallel and 141 in series.
Full speed, 2 in. parallel and 282 in series.
Revolutions, 2000 per minute.
Weight, 4410 lbs. Giving 200 to 210 ampères at full load.

The boat had a reserve of buoyancy, and was forced under water by vertical propellers in a similar manner to the Nordenfelts, and when submerged had a speed of 6 knots. In the first trials a single horizontal rudder was carried, but this was so unsatisfactory that anything like an even depth-line was impossible to maintain without great efforts on the part of the coxswain on the diving-wheel. To overcome this two hydro-planes † were introduced, and these made the angle of dive less and gave a far better control over the depth-line.

The "Gymnote" was first tried in the month of September 1888, in Toulon harbour, before the maritime Prefect, with medium results. She kept a bad depth-line, and the electric accumulators were very poor indeed.

Subsequently the boat was used for experimental purposes and the instruction of submarine crews; but many new ideas have been tried in her for the first time and, when perfected, were placed in more modern boats. The torpedoes are now carried in frames as in a "Goubet" submarine.

To-day this vessel is in commission as part of the *défense mobile*

* 1 lb. = 0·453 kilogrammes.

† *i.e.* side rudders, see Chapter XVI, on Stability.

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of Toulon, and we occasionally hear of her indulging in a small battery gas explosion, or finding the bottom * when running submerged.

"Gustave Zédé"—1891.

The "Gymnote" trials proved fairly successful, but it was recognised that she scarcely fulfilled the requirements of a service submarine. In 1890 M. Romazzotti submitted designs of a new boat, which was called the "Screve," the lines of the "Gymnote" being taken and expanded and also all her good points closely followed.

During the construction the famous engineer, M. Gustave Zédé, died, and, to pay a last tribute to this great man, the Minister of Marine issued instructions that the "Screve's" name was to be altered to "Gustave Zédé."

The dimensions are:

Length	.	148 ft.
Diameter	.	10·9 „
Displacement		266 tons.

She was launched on July 1, 1893, from the slips of Mouillon at Toulon.

As the "Gymnote" was only 59 ft. 10 in. this was a venturesome expansion, and was what really prevented the "Gustave Zédé" from being the success that was anticipated. The hull was built of seventy-six frames covered with a non-magnetic and non-corrosive metal called Roma bronze, and had fine ends covered with a light superstructure, which formed a flat deck from right forward to two-thirds of her whole length. The means of taking in water ballast are the same as in the "Gymnote."

In the first trials the conning-tower was telescopic, as in the "Gymnote," but this was found unsatisfactory from the same causes and abandoned for a fixed one, which was subsequently armoured; the necessary switches for starting and stopping the motors, the key for firing torpedoes, etc., were placed in this tower. The wheels for steering and diving were directly underneath so as to enable the captain, when working the boat from the conning-tower, to have all the controlling mechanism under his eye (Fig. 20, Plate 21).

* In diving exercises off Toulon, March, 1907, the "Gymnote" struck a rock with considerable force; safety weights were at once slipped and the boat brought safely to the surface.

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The armament consists of one torpedo tube fixed in the bow, three small 15-in. torpedoes are carried, one in the tube and two spare stowed abaft the tube on either side. The motive power was at first derived from 720 Lancent cells of 29 plates each, which drove two Thury type electric motors of 360 E.H.P.; these were six-polar machines, separately excited, being constructed by M. Sautter-Harle; when coupled in parallel and mounted tandem fashion they drove a three-bladed propeller at about 250 revolutions per minute, giving a theoretical speed of 11 knots on the surface and when submerged 8 knots. The weight of the battery was excessive—130 tons, and that of the motors 27 tons. With 720 cells it was found necessary to place them in two tiers. In this arrangement the connections could not be got at or densities taken very easily. Short-circuits were rife, and what with sulphating going on, paste dropping out and making shorts between the plates, the cells were in a bad way. After one or two fires resulting from short-circuits between the upper and the lower tier, the whole battery was dismantled and re-constructed, the elements were reduced from 720 to 360, and also by two plates each, so as to provide better insulation between the plates.

In the first trials the battery was not the only source of weakness; the boat could not be kept at an even depth-line when submerged, and several modifications were necessary to the diving gear. An ordinary vertical rudder gave the direction in the horizontal plane. At first she was fitted with diving rudders right aft; these were not powerful enough, as, even with a very small reserve of buoyancy, it was difficult to keep the boat under control in the vertical plane.

With the committee of engineers on board, her performances in attempting to keep an even depth-line were most erratic, and frequently a 30° inclination was reached before the boat could be brought up; on one occasion she hit the bottom in 10 fathoms with sufficient force to unseat the engineering experts.

After these trials additional auxiliary rudders were introduced; the dive could then be controlled by a set of horizontal rudders at the stern, two amidships, and two right forward. These extra diving rudders are frequently alluded to in submarine designs as hydro-planes; they are made of stout steel plates worked by hyadrulic mechanism. The coxswain, sitting at the foot of the conning-tower, controls the diving rudders with one lever and the hydro-planes with the other. With these extra rudders the

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incliuation when diving has been reduced from 12° to 5°. Like the "Gymnote," water reservoirs are used to regulate the fore and aft trim, the water being blown forward or aft as required by compressed air.

Two air-pumps are provided, worked by electric motors; these pump up the air reservoirs, charge and fire the torpedoes, also supply the air for blowing through the boat.

When discharging a torpedo an automatic bow-cap is knocked down at the moment of firing. The torpedoes in this boat are small, and on leaving the tube scarcely affect the longitudina stability, a caution to the man on the diving levers being alone necessary. The crew consists of one lieutenant, a sub-lieutenant, and ten men. In a heavy seaway the "Gustave Zédé" has got within a thousand yards of a battleship in broad daylight without being seen by any of the fleet, and easily evaded torpedo-boats at a much closer range; also, during a passage from Toulon to Marseilles, she has displayed good sea-going qualities, and in experiments carried out in the Rade des Salins she torpedoed the "Magenta" without that ship being able to bring a single gun to bear on her. The "Marceau," with the "Neptune," took part in this manœuvre, and the unbiassed opinion in the three battleships was that in time of war the submarine would not have been touched by gun-fire.

After first being almost a complete failure, by sheer persistence of effort in overcoming great difficulties the "Gustave Zédé" has been turned by her designer and French naval officers into a formidable weapon. The successes obtained in peace manœuvres appealed to the scientific side of the French nation, who may be pardoned for their exuberance over what were various smart seamanlike performances of her captain. A flying bridge has been fitted before the conning-tower (Plate 21), to provide additional comfort to the crew and allow them on deck for an airing if the weather is not too boisterous. When preparing for diving, the bridge can be lowered in a few seconds.

"Morse"—1898.

Before the construction of the "Gustave Zédé" was completed, M. Romazzotti brought out designs for a submarine of lesser tonnage. The advance from the "Gymnote," with a displacement of 30 tons, to the "Gustave Zédé," of 266 tons, was recognised as being too rapid,

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therefore experiments with a medium size was considered advisable. The plans took a long time before being finally approved; but eventually a boat was launched at Cherbourg, on July 5, 1899, named the "Morse." Her dimensions were:

Length . . .	118 ft.
Maximum diameter .	8 ft. 3 in.
Surface displacement .	136 tons.

The lines and internal arrangements of the "Gustave Zédé" were to a great extent followed (Fig. 21), the material of the hull being also made of Roma bronze. The motive power is furnished by a battery of accumulators manufactured by the Société des Métaux; this supplies electrical energy to a six-pole Thury separately excited motor of 360 E.H.P., the shunt coils being excited by an auxiliary battery of 100 volts.

The armament consists of one tube in bow and two sets of drop collars, one torpedo being held in them on each beam. Three torpedoes are thus always carried.

The crew is made up of one officer and eight men. The trials were successful, the boat attaining a speed of nearly 8 knots, with a radius of about 100 miles at 7 knots. An interesting account is given in a French journal* of some experiments undertaken before the Minister of Marine, from which the following few extracts have been taken.

"The forward end of the 'Morse' is fitted with a torpedo discharging-tube, and at the after end is the propeller. From the tube to the motor extends a long passage having at the sides two rows of accumulators superimposed. In the centre, under the captain's conning-tower, which is reached by an iron ladder, are all the levers and handles for working the machinery which moves the boat both in a vertical and horizontal direction. Above are two manholes, one communicating outside with a narrow platform of lattice-work raised about 30 centimetres (11 in.) above the hull of the vessel, and under which the water is free to pass; the other with the conning-tower, which itself has also a manhole communicating with the outer air besides the three small glass scuttles, all of which can be hermetically closed from the inside. Under the horizontal deck, which extends

* Extract from *Le Yacht*.

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almost from end to end, are ballast-tanks, which can be filled at will with water when it is desired to submerge the vessel. When submerged she is guided by means of the periscope, an instrument which projects above the water when the boat is submerged to any depth up to 6 metres (19·6 ft). This ingenious device reflects everything within its field of vision, and can be turned round so as to cover the whole horizon.

"When the Minister of War had thoroughly inspected the 'Morse,' orders were given to get under way, and she proceeded from the dockyard basin out into the harbour. A considerable sea was running outside, sufficient to make the steam-launch which followed behind, and in which the Minister of Marine had taken his seat, pitch and roll considerably. The 'Morse,' however, was wonderfully steady, only rolling very slightly. After crossing the harbour she steered towards the 'Imprenable' hulk, which serves as a workshop and quarters for those engaged in adjusting torpedoes; here she awaited orders to submerge, which were soon after given. The ballast-tanks then commenced to fill, and in a few moments the voices of the men in charge were heard reporting, 'forward tanks full,' 'after tanks full,' 'midship tanks full'; the manholes were then closed and the 'Morse' commenced to sink; the water rose first over the scuttles, and finally over the conning-tower, allowing only a bluish light to filter through the glass. The whole operation of submerging does not take more than a few minutes to complete. The periscope, having a diameter of only 10 centimetres (3·9 in.), is quite invisible at a short distance.

"The feeling experienced at the moment the vessel is making her descent is most peculiar; it is one of expectancy; but nothing happens. One is astonished at the quiet, the absolute calm, there is no movement, not even a tremble; the waves wash overhead without causing the least vibration, the motor works silently, and the vessel glides through the water without causing any bow wave or leaving any track. Alone the voice of the captain is heard, who, standing by the periscope, gives his orders for so many degrees of helm and so many revolutions of the engine. The little vessel is now almost in equilibrium and would sink deeper or rise to the surface were it not for the 'ailettes' * on each side which serve to prevent this. Before

* Hydro-planes.

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an instrument which indicates the depth stands a petty officer with his eye fixed and his attention concentrated on the pointer, and by turning a wheel he causes the 'ailettes' to act so as to maintain the vessel at the required depth. Should she for any reason continue to descend or refuse to ascend, a false keel can be detached, which would cause her immediately to rise to the surface; but after this the buoyancy would be so much increased that she could no longer be submerged even with all the ballast-tanks full. Orders had been given to remain a quarter of an hour under water, and at the expiration of the time pumps are set in motion and the water was forced out of the ballast-tank, and the 'Morse' commenced to rise, the conning-tower and the small platform emerge, and the manholes are opened; no commotion takes place at the entry of the external air, and no inconvenience has been felt by those on board during the dive, the act of breathing being as free and regular as in the open air. Trials to ascertain the habitability of the 'Morse' had already been made, and she has remained for eight hours under water, the crew experiencing no difficulty in breathing and no buzzing sensation in the ears, no excitation or inconvenience of any sort, and it was considered they could have remained double the time if necessary, the chemical analysis of the air showing also that it would have been possible to considerably prolong the trial if required."

It is interesting to note that a petrol engine was for some time under consideration for the "Morse," but, in spite of the success obtained by Mr. Holland in this direction, the idea was abandoned as being too complicated! The French engineers were naturally rather disappointed, and openly complained that their Government gave them scanty assistance in developing new ideas compared to what was being done in other countries. The experiences of Holland, Lake, Nordenfelt, etc., hardly confirm this contention.

"Narval"—1896.

In February 1896 a great step was made in the evolution of the submarine boat. The official mind in France began to recognise more and more that this type of vessel might be of some considerable use in the future, and that further experiments were most desirable. The Minister of Marine, M. Lockroy, therefore invited designs for a submarine boat not exceeding 200 tons displacement, the radius

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of action to be 100 miles at 12 knots on the surface and 10 miles at 8 knots when submerged. The competition was open to the world, and twenty-nine designs were submitted to the Commission detailed to examine the various plans.

The Commissioners decided to accept the design of M. Laubeuf as being most likely to fulfil the requirements, and in doing so presented him with a gold medal. In connection with this boat the name submersible arose in order to distinguish the new type from the purely submarine boats like the "Gymnote," "Gustave Zédé," and "Morse," which, as we have seen, rely on a battery of accumulators for furnishing electrical energy for their motive power.

M. Laubeuf's designs differed from the above as he arranged for two distinct methods of propulsion, the one for running on the surface and the other for use when submerged. This method gives the boat an extended range of action for surface work and enables her to act as a second-class torpedo-boat. A submarine on these plans was laid down at Cherbourg in 1897 and was launched on October 26, 1899, under the name of the "Narval." Her dimensions are:

Length . . .	111 ft. 6 in.
Beam . . .	12 „ 4 „
Draught in light trim .	5 „ 3 „
Displacement, light trim	106 tons.
Displacement submerged	168 tons.

The hull is constructed on the principle that a freely circulating body of water between the inner and outer shell is the best protection against an explosion caused by a gun-cotton charge placed in vicinity of the boat.

The inner hull is of circular section, the maximum diameter being in the centre of the boat, then tapering away to the bow and the stern, the steel plates, $\frac{8}{16}$ in. in thickness, are rolled to fit the circular rings.

The external hull is made of lighter steel plates, about $\frac{3}{16}$ to $\frac{4}{16}$ of an in. thick, and is not quite circular, the upper plates forming a flat deck running fore and aft.

The space between the two hulls, utilised for water-ballast-tanks

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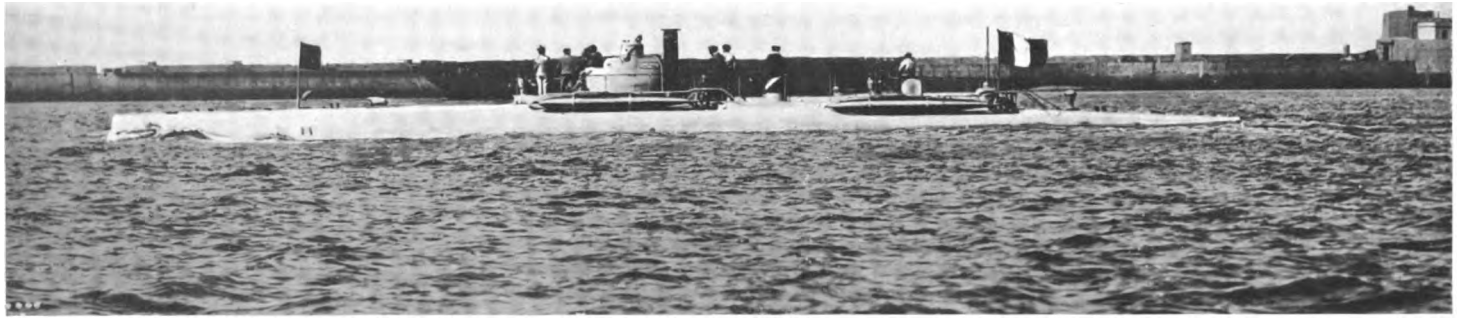

PLATE 22.—*THE "NARVAL."*

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to decrease the buoyancy before submerging, also provides tanks to compensate for various weights carried and consumed, such as oil, fuel, etc.

A new departure in these designs was made with a view to obtain better control in the vertical plane, as shown so necessary with the "Gustave Zédé," therefore four hydro-planes were fitted, two forward and two aft.

The increase of diving-rudder area enabled the oblique dive to be reduced to a minimum and prevented the sulphuric acid from spilling out of the accumulators. These hydro-planes are worked on the same axle.

The boat is brought from surface trim to the position for diving in twenty minutes, that is, with the surface of the water a foot or so up the conning-tower; a man is stationed at the wheel that works all four hydro-planes simultaneously. The electric motors are started by means of a controlling switch, the grouping switch being put to half or full speed as required and the dive made.

For submerged work a battery of 158 elements of the Fulmen type is fitted, furnishing the energy necessary for running a motor which gave a speed of 8 knots for a range of 25 miles and that of 5 knots for a range of 72 miles. This motor can be used as a dynamo and run off the main engine for charging the accumulators either at rest, on the surface, or when the boat is running, the only precaution to be taken is to see that the battery fans are kept going so as to remove the gases given off during the process of charging up the cells. For surface running an Adolphe-Seigle system of tubular boiler, heated by five heavy oil-burners for stoking with heavy petroleum, was fitted, being constructed by Messrs. Brûlé and Co.*

This boiler supplied steam for a 250 H.P. triple-expansion engine.

The range of action on the surface was

250 miles at 11 knots.
500 „ 7·5 „

Off the main shaft can be run an air-pump for pumping up the compressed-air flasks, by means of which the ballast-tanks are cleared of water.

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* See Chapter XVII.

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The armament consists of four 17·75-in. torpedoes, which are fired from two Drzewiecki* frames on each side of the boat. The advantage of this apparatus, invented by the great Russian engineer in 1893, is that, by their use, a torpedo can be fired from an angle of 10° from right ahead up to one of 160°

Plate 22 shows the "Narval" fully equipped under way, that is, with all stores, torpedoes, fuel, etc. on board. Diagrammatically her trim would look as in Fig. 22, I. Water ballast can then be taken in for bringing her to diving trim, as Fig 22, II, that is, with upper deck covered a few inches. The boat is now ready for diving. Then by going ahead and putting helm as required on the horizontal rudders and hydro-planes, the boat is brought to Fig. 22, III, with only the periscope showing.

By diving still further the boat can be run as in Fig. 22, IV, with nothing showing at all on the surface except a few bubbles; these will not even be noticeable in a calm sea if a depth of 20 ft. is maintained by the manometer. During the preliminary trials the free surfaces of water in the double hull gave some trouble and necessitated more subdivision of the tanks. It may be remembered this free surface was an unfavourable feature of the Nordenfelt designs.

On completing the inspection of the "Morse," previously referred to, the Minister of War joined the Minister of Marine on board the "Imprenable," and the next trial was with the "Narval."† "On the surface she acts like an ordinary torpedo-boat, the engines being worked by steam; when submerged she becomes a submarine boat, and the motive force is electricity. She has a displacement of 106 tons and is not cylindrical in shape like the 'Morse'; her upper works, being flat, form a deck, and the conning-tower, funnel, and periscope project above this, giving her at a distance a novel and peculiar appearance. The submerging of the 'Narval' is a rather delicate operation; the motive power has to be changed, the funnel, etc., has to be drawn in; sufficient time must be allowed for the unused steam to cool down, and a much greater quantity of water than in the case of the 'Morse' has to be introduced into the ballast-tanks to overcome her buoyancy. Great progress has been made in these respects since her first trials, and the operation of submerging

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* See Chapter XXII.

† Extract from *Le Yacht*.

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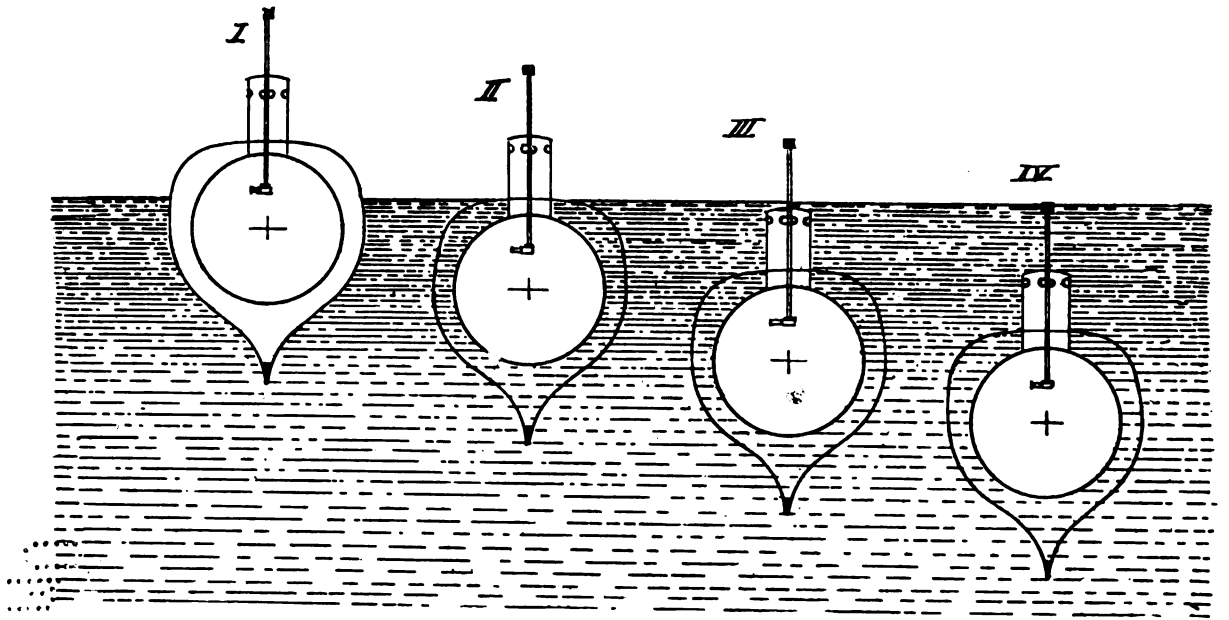

FIG. 22.—*SUBMARINE "NARVAL" IN FOUR CONDITIONS OF TRIM.*

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has been much accelerated, but it still takes considerably longer than in the case of the 'Morse.' On the present occasion submergence was effected in a quarter of an hour, and when submerged the only thing visible above the water is the periscope. The trials were suspended at 11.30 a.m. In the afternoon the Ministers again went on board the 'Imprenable' to witness torpedo practice from the submarine boats 'Morse' and 'Narval.'

"The 'Morse' has three firing positions; the bow-tube, with air impulse, and two special carriers on the side, each holding one torpedo, which, when fired, are simply detached and proceed with their own motive force; all three can fire only in the axis of the vessel. Four shots were fired, and in each case the torpedo ran straight. The 'Narval' has four discharging positions, on the system invented by M. Drzewiecki, which allows the torpedo to be fired in any direction. Four shots were also fired, but with not quite such satisfactory results as from the 'Morse'; but the day was drawing to a close, and the light was bad. The Ministers expressed themselves well satisfied with what they had seen, and returned to Paris in the evening."

Using oil fuel to heat the boiler for raising steam does not readily lend itself to submarine design as it takes too long to generate and then allow the boat to cool down before diving, also, when hermetically closed, the heat is very unpleasant. With later boats the introduction of internal-combustion engines of various types has got over these difficulties. To illustrate the constructive strength of the "Narval" the following may be of interest.

"On leaving Cherbourg harbour some months ago she came into collision with the tug-boat 'Navette,' which was travelling at right angles to the course of the submarine. The officer of the latter observed the approaching tug, and immediately reversed his engines, the 'Narval' at the time making a speed of 5 knots. Although the momentum of the submarine was thus considerably reduced, she struck the tug-boat with sufficient force amidships to force her nose through the hull of the latter to the extent of 16 in., and the tug ultimately foundered in 4½ fathoms when the bow of the 'Narval' was withdrawn."

This is a lesson not to be lost sight of in considering the offensive power of a submarine, and shows her in a new rôle, which opens up a fresh line of thought as to the ramming powers of these vessels.

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The Spanish submarine "Peral," it may be recalled, was built for ramming purposes in addition to her torpedo armament.

A boat having fired away all her torpedoes, if hotly pressed by a destroyer, might find this the most effectual way of dealing with her surface opponent.

The twenty minutes taken to reduce the buoyancy before the dive can be made is the chief disadvantage of the "Narval"; also the steam method of propulsion is unsatisfactory. In spite of these drawbacks this submarine has been a great success, and the experiences gained in working her have been invaluable in furthering submarine designs.

Part II.

After the conclusion of the Franco-German war public opinion emphasised that greater attention in the future must be given to the French Army; this policy was carried on for many years, as we read. Prince Bismarck, whilst in power, did not forget to remind France that any neglect in this direction would ensure future retribution. Warship construction showed no particular line of policy until 1899, in which year a *contretemps* occurred with another Power, and the French nation suddenly woke up to the fact that perhaps too much attention had been given to the army and not enough to the navy. They found themselves in the unenviable position of having a somewhat neglected fleet.

French writers on maritime warfare were then gradually led to recognise three main divisions, which they named

La guerre d'escadre,
La guerre de course,
La descente,

for the following reasons.

They considered the first as practicable in fighting a Power like Germany; France, they maintained, needed battleships for such a war, but this method has long been abandoned in view of a conflict with England. They argued a glorious defeat was all they could expect, as they would be crushed by the mere weight of numbers; and each year's building programme in the island across the Channel made this conclusion inevitable. Therefore, whilst still maintaining a moderate

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fleet of battleships, the new school inculcated by Admiral Aube and M. Lockroy resolved to fall back upon the second mode of fighting; this was to have numerous fast-raiding cruisers, such as the "Guichen" and "Château-Renault," which sacrifice everything for their 23-knot speed, and to use these for harassing commerce. For the purpose of protecting the country's important harbours and coast-line, great attention was to be devoted to the development of the submarine boat, the value of which, as a naval unit, was then beginning to show great possibilities.

Admiral Aube's compromise was partly due to the perseverance of the French engineers in placing their country in the most forward position of any nation in regard to experimental work of a sub-aqueous nature, and also to the fact that a mobile defence worked out on these lines was most economical.

This policy has been the chief stepping-stone in the evolution of submarine vessels, and marks the commencement of a period of exceptional progress in their modern history.

If France is to maintain her lead in submarine-boat construction a definite progressive policy is necessary, and not one that may be subjected to the caprices of successive Ministers of Marine, alternating between submarines and submersibles of large and small tonnage, to say nothing of encouraging amateurs in designing under-water vessels before they have grasped the rudiments of surface requirements. It would be far better to have fewer boats of a more homogeneous class than many of different types, as the latter do not lend themselves to organisation in mobile flotillas. The reliability of the modified "Narval" type is undisputed; they have been for over two years working in the Channel, and have proved themselves a distinct success. These boats were constructed from the plans of M. Laubeuf, the able Naval Engineer-in-chief. If M. Pelletan had ordered more of this design, using internal-combustion motors in lieu of steam power for propulsion on the surface, instead of wasting money on small boats of the 50-ton "Guêpe" type, it would have been better for the development of this means of defence. Fortunately for France the pendulum has begun to swing in the opposite direction. M. Lockroy, one of the former leaders of the new school, has, in a series of letters written to the *Temps*, modified his ideas of constructing fast cruisers to harass commerce, etc.

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His doctrine has failed to put the French marine on a sound basis. Under the present Ministry we notice the 18,000-ton battleship and cruiser being developed in their respective spheres, and the submarine vessel, not given a position of exaggerated importance, but put in her proper place as a useful adjunct of a modern navy.

When the "Narval" was designed with a separate motive power for surface and submerged work, the name "submersible" was introduced to distinguish this boat from the submarine proper, with only one propelling agent, as electricity, for both these duties. Latterly, however, it has been customary to distinguish the submarine from the submersible on purely a matter of displacement.

The submarine, as now understood, is a vessel that, when on the surface, is almost awash, and possesses from only 7 to 8 per cent. of her displacement above the water-line when in her lightest trim.

To overcome the reserve buoyancy in this condition only a small quantity, some 20 tons, of water ballast in a 100-ft. boat, has to be admitted to place her in diving trim; whereas, in a boat like the "Narval," 50 to 60 tons of water ballast has to be taken in before she is ready for diving. In the 400-ton submersibles recently laid down, 30 per cent. of their displacement is out of water, consequently about 120 tons of water has to be admitted. This necessitates a considerable amount of time elapsing before the dive can be brought off. Such delay would be disastrous if the boat was surprised in the light condition by a watchful destroyer. The sole protection of under-water boats is their capability of rapid disappearance, therefore designers in all countries are endeavouring to reduce this time to a minimum.

The submersible, by reason of its larger size, has a greater hygienic advantage over the submarine, also the crew can use the deck in reasonable weather, whereas in the latter they can only foregather on a small flying bridge, as the water is practically always washing over the deck in all but the calmest of weather. However, their one great advantage is being able to disappear quickly.

Early in 1899 M. Lockroy, speaking on the French Navy estimates, said:—

"Formerly France had but one naval rival, but she now has four, and the Triple Alliance could muster 67 battleships, while England had 95 and France 60. Could France ensure superiority over her rivals? Yes, submarine navigation ensured her an

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unquestionable advantage. This line of policy, brought partly into existence by the 'Affaire,' gave another great impetus to submarine-boat construction, one effort being the national subscription raised by the French newspaper *Le Matin*. The interest in these weapons was really of a substantial nature, which resulted in the large sum of 300,000 francs being raised, mostly in small contributions. This amount was presented to the nation for the purchase of two submarine boats, which were built from the designs of M. Romazzotti and embodied many improvements on their prototype the 'Morse.'"

"Français" and "Algérien."

The first boat, named the "Français," was launched at Cherbourg in January 1901, and the second, the "Algérien," in the following February. The hull of each boat was constructed of steel, with a

Length of . .	118 ft.
Beam . . .	9 ft. 2 in.
Surface displacement	143 tons.
E.H.P. . . .	250.

The motive power was furnished by electric accumulators providing energy to a motor for rotating the single screw-propeller. The radius of action was 100 miles at 8 knots. The armament consisted of four torpedoes carried in Drzewiecki drop collars. The constructive strength of the "Narval" has evidently been repeated in the "Algérien," as it may be recalled that during some evolutions the captain of the submarine miscalculated his distance and came into collision with the armoured cruiser "Kléber." The "Algérien" was considerably damaged, but got safely into dock.

The cruiser came off badly and had two out of three propellers damaged and their shafts bent. That the submarine should be able to inflict so much damage to the cruiser and escape disaster herself speaks well for her construction.

"Farfadet" Class.

At the same time as the "Algérien" and "Français" were laid down the Government gave the order for four boats to be built at

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Rochefort from the designs of M. Maugas, chief naval constructor. These were the

"Farfadet," launched 17.5.01.
"Gnome" „ 24.7.01.
"Korrigan" „ 25.1.01.
"Lutin" „ 18.6.03.

The hulls were all built of steel and have the following dimensions:—

Length . . .	134 ft. 7 in.
Beam . . .	9½ ft.
Surface displacement	185 tons.
Buoyancy . .	8 per cent.

The motive power is electricity furnished from accumulators to a single motor, which runs at about 250 revolutions. This gives a speed of 9 knots on surface and 7 knots submerged; four torpedoes are carried in Drzewiecki collars.

The crew number one officer and eight men. Of the above the "Korrigan" is well known, as she has frequently run into the inner harbour of Bizerta from seaward, the conning being done by means of the periscope only.

On one occasion she successfully torpedoed the cruiser "Tempête," when doing duty as guard-ship in the Bay of Ponty, without being observed; also this boat has remained submerged from six in the morning to six in the evening without the crew experiencing any discomfort during their long confinement.

The "Korrigan" and the "Farfadet" were towed from La Rochelle to Bizerta in 1904, and now form a portion of the *défense mobile* at that port (Plate 23).

It is with the greatest regret that, in 1905, an accident to the "Farfadet" has to be recorded in this book, the more so as we are painfully reminded of our mishap with "A 8" submarine at Devonport. From the press accounts the disaster may be reconstituted as follows:—

The captain was manœuvring his boat in the calm waters of the lake of Bizerta, some 500 yards from the arsenal at Sidi Abdullah, and gave the order to flood the ballast-tanks; the boat, with all kingstons and vents open, took in water ballast quickly and soon gained downward momentum. This is very noticeable in some

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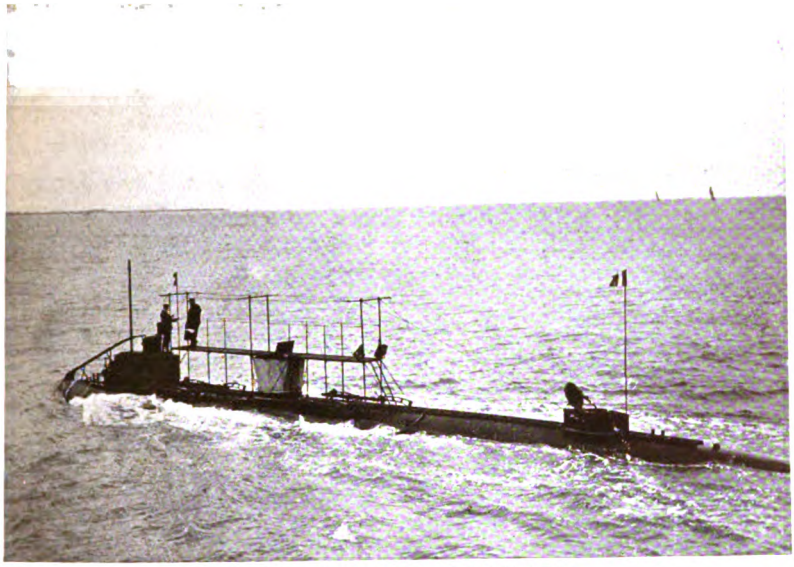

PLATE 23.—*SUBMARINE "FARFADET."*

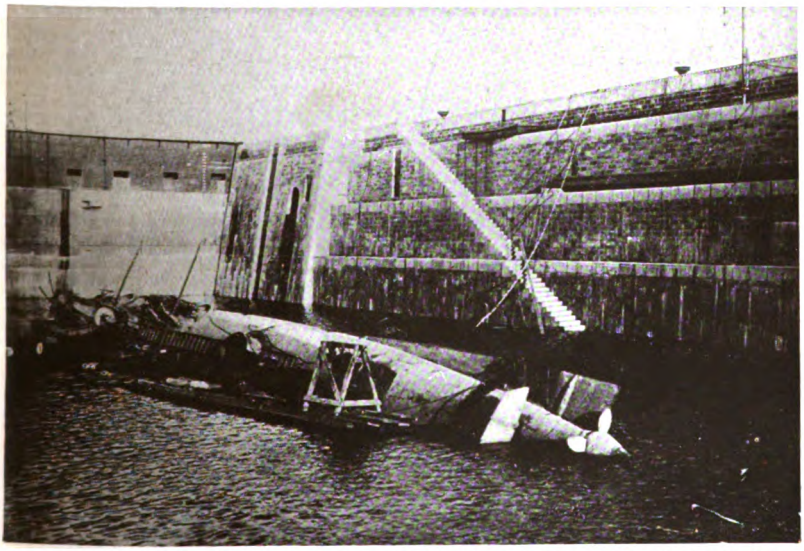

PLATE 24.—*THE "FARFADET" IN DOCK AT BIZERTA AFTER THE ACCIDENT*, 1905.

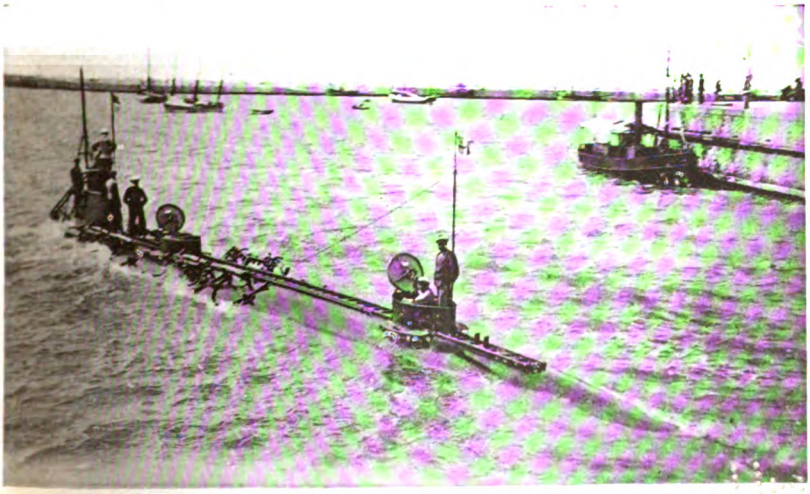

PLATE 25.—*SUBMARINE "LUTIN," SUNK AT BIZERTA*, 16*th* OCTOBER, 1905.

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boats; if water is taken in too quickly they dip right under the surface, even with several hundred pounds of buoyancy, and then quickly reappear. Too much downward momentum is usually prevented by closing the kingstons in good time and then cracking a valve to completely fill the tanks. In this case the boat had way on, and for some inexplicable cause the conning-tower hatch failed to close; the captain opened it a little, with a view to slamming it down, when it was forced from his hand by the water coming up the conning-tower. Large volumes entered the boat down the opening and caused the air from the interior to be expelled; this forced to the surface first the captain of the boat then two of his crew. The boat sank to the bottom head foremost and buried her nose deeply in the mud, with ten of the crew imprisoned in her. Salvage operations were immediately undertaken, but the resources of the port were naturally limited, and, after many great attempts, all hope of saving the crew was abandoned.

Considerable difficulty was experienced in raising the boat owing to the tenacious nature of the mud at the bottom of the harbour; it was even necessary for the divers to tunnel under the boat to pass the hawsers and chains, which enabled her to be raised off the bottom by means of a floating-dock used for docking the torpedo-boats of the *défense mobile*. The submarine, after a few days, was taken into dock. Plate 24 shows her whole length with the starboard side uppermost.

The disaster to the submarine "Lutin" (Plate 25) at Bizerta,* following such a short time after the "Farfadet" calamity at the same port, was a terrible blow to our neighbours across the Channel. As soon as the mishap became generally known a telegram was despatched to Malta asking for any assistance that could be rendered.

In answer to this call for aid Lord Charles Beresford† promptly despatched the battleship "Implacable," armoured cruiser "Carnarvon," and destroyer "Albatross," with special salvage appliances, under-water illuminating lamps, etc.

On arrival at the scene of disaster, sweeping operations were found well in hand, and, with the extra help, the lost submarine was

* October 16, 1906.

† Then Commander-in-chief, Mediterranean.

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soon located. The assistance so smartly sent from Malta was of no avail, as the "Lutin," when examined by divers, was found full of water, with all chance of saving the lives of her brave crew gone.

It is generally considered that the accident to the "Lutin" was in no way caused by the human element being at fault, but by the kingston valve in one of the after ballast-tanks failing to close the tank against the external fluid pressures.

The submarine was carrying out diving exercises, that is, with a few hundred pounds of buoyancy only. As the boat was running under water the reserve buoyancy was destroyed by water filling up the tank through the faulty kingston valve. In such a condition the merest touch of the diving rudders will cause a boat to dive to an excessive depth. This occurred, and the fluid pressures, acting through the faulty kingston valve against the interior walls of the tank, caused straining of the stays and leaks through the sides of the tank into the interior of the boat.

At depths up to 120 ft. this extra pressure would do little damage to the hull, but in this case the tank was considerably weaker than the hull. On danger being noticed the captain of the submarine let go his safety weights, but unfortunately all did not slip, as his boat was seen to just reach the surface and then sink. Her stay above water was so short that the crew had not sufficient time to escape by the conning-tower hatch, and the boat sank in about 100 ft.

In connection with this accident mention might be made that the first Inspecting Captain* of submarine boats discerned at once that a risk existed, in the early British Holland design, of the internal walls of the main ballast-tanks being forced in by external fluid pressures that the hull of the boat could stand easily. Consequently all the ballast-tanks of the first five Hollands and subsequent boats were stayed up to make them structurally as strong as the hull of the boat, thus making an accident in our submarines similar to that which occurred to the "Lutin," in normal depths of water impossible.

As soon as it became evident that the British ships could be of no use in saving the "Lutin's" crew, Captain Patey, of H.M.S "Implacable," took leave of the Minister of Marine, who had arrived at Bizerta, and said he was deeply touched by the thoughtfulness of M. Thomson, in the midst of his manifold anxieties, in visiting him

* Captain Bacon, R.N.

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on the "Implacable." He and his officers would have wished to render the last honours to the victims of the "Lutin," but their duties and the uncertain weather prevented that. They would, none the less, have stayed had they thought they could be of use, but the salvage apparatus at hand rendered their presence superfluous.

M. Thomson said:—

"I am deeply grateful to you for the sympathy and loyal friendship which you have shown us on this sad occasion in the name of the British Navy. I beg you to tell Lord Charles Beresford how greatly we are touched by the promptitude with which he placed at the disposal of the port of Bizerta all your available resources, and by the rapidity with which your ships came to join their efforts to ours in the attempt to save the 'Lutin.' I had already received, in Paris, the telegram from the First Lord of the Admiralty (Lord Tweedmouth) expressing the condolences of his Government and of the British Navy, and had thanked him for it. I now repeat to you the thanks of our country."

The "Lutin" was subsequently raised by means of the floating dock at Bizerta, and on examination of the wreck the larboard kingston of the after ballast-tank showed marks on the face of the valve, where it had been screwed down against a hard substance. Six rivets had sheered, and the whole ballast-tank was badly strained from the extra pressure it had been subjected to.

The sides which gave way were calculated to stand a pressure of 35 lbs. per square inch, and it will be understood that when the dive exceeded 82 ft. this resistance was insufficient to prevent the external fluid pressures bursting the tank.

The commission of enquiry recommended that all ballast compartments should be made of equal strength with the hull.

The pebble, the cause of the kingston valve failing to close properly, is rather larger than a walnut, with flat sides, and shows traces of the pressure brought to bear on it by the valve.

These are the only two serious accidents France has had since Admiral Aube decided to introduce submarines into her navy, truly a great record for the workers in this strenuous enterprise.

The present Minister of Marine, M. Thomson, has not allowed these sad occurrences to alter his policy in the direction of perfecting the submersible.

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"Naïade" Class.

The Budget of 1901 provided for twenty boats of the small "Naïade" class (Plates 26 and 27), designed by M. Romazzotti and given the following names :—

"Naïade."	"Protée."	"Perle."	"Esturgeon."
"Bonite."	"Thon."	"Souffleur."	"Dorade."
"Lynx."	"Ludion."	"Loutre."	"Castor."
"Phoque."	"Otarie."	"Méduse."	"Oursin."
"Grondin."	"Anguille."	"Alose."	"Truite."

They were all built with steel hulls, and have a

Surface displacement of	68 tons.
Length . . .	77 ft.
Beam . . .	7 „ 5 in.
Maximum depth	7 „ 11 „
Buoyancy . .	5 per cent.

Electrical energy is furnished from accumulators for driving the motor coupled to one propeller. The speed obtained was 8 knots on the surface and 5 knots submerged.

These boats were built at the following places :—

Cherbourg . . .	4.
Toulon . . .	10.
Rochefort . . .	6.

It may be noticed that, unlike the practice in this country, all the French submarines are built in the Government dock-yards and not by private firms. The crew number one officer and four men, and are considered sufficient to work the armament, which is composed of two torpedoes carried in Drzewiecki drop collars (Plates 26 and 27).

Most of these boats were modified in design before completion and then fitted with benzoline internal-combustion motors for increasing their radius of action on the surface. From all accounts it appears these motors have not been very successful, and a recent *

* July 1906.

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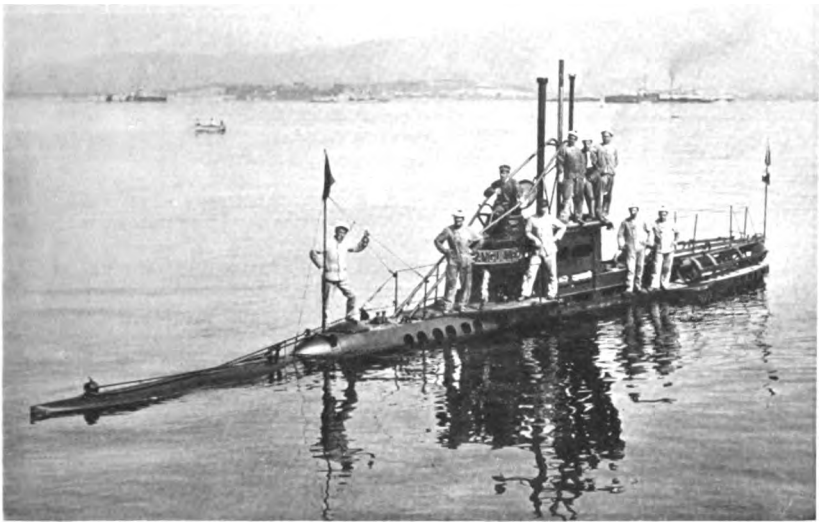

PLATE 26.—*SUBMARINE "ANGUILLE."*

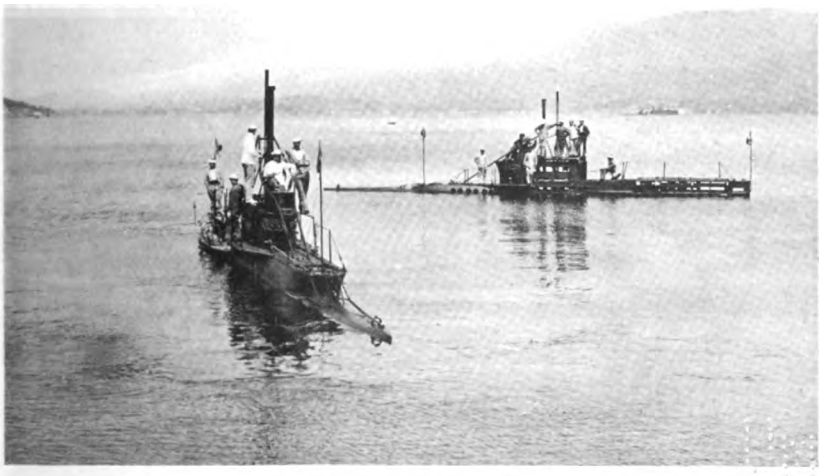

PLATE 27.—*"ANGUILLE" AND "GRONDIN."*

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Ministerial order has forbidden further use of them, and no more benzol is to be used on board the submarines of this class; reliance is to be placed on electricity for both surface and submerged work.

In June 1904 the "Lynx" and "Protée" had all their movable weights taken out and were hoisted on board the torpedo depôt ship "Foudre," then taken to Saigon for the *défense mobile* of that port. Since that date two more boats have been sent out, making the distribution of the twenty boats of this type as follows:—

3 at Dunkerque.
5 at La Pallice.
8 at Toulon.
4 at Saigon.*

There is a question of sending the boats at Toulon and La Pallice to other stations such as Algiers, Oran, Corsica.

Of this group, the "Bonite" has distinguished herself in some manœuvres held off Toulon, in February 1906, by torpedoing the armoured cruiser "Condé" and the battleship "Iéna" at close range.

On completion of these successful attacks, an attempt was made by the submarine to torpedo the flagship "Suffren," but owing to the surface ship altering course whilst the submarine was attacking, the captain of the latter vessel, on bringing his periscope out of water, found himself so close to the "Suffren" that, in an attempt to dive clear of her, a violent collision took place.

The shock experienced in the under-water vessel was tremendous, but the crew, being well trained, quickly slipped the safety weights, then emptied the ballast-tanks and brought the boat to the surface without further mishap.

On arrival of the submarine at Toulon it was found that the whole stem was concertinaed, the foremost trimming-tank bulged in and several adjoining plates badly buckled. The "Suffren" suffered badly and had to be docked at Toulon to repair a large hole made in the starboard side below the armour deck. This incident is another proof of the structural strength of the French submarines.

These submarines now use the electric motors only, and with them have taken a successful part in the defence of Toulon and Marseilles during the last grand manœuvres, but their small size and accommodation condemns them to a defensive rôle.

* *Le Yacht*, November 3, 1906.

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The French Government were not satisfied with only one motive power in their submarines, considering that America and England were doing successful work with internal-combustion engines. Therefore three submarines were designed and known under the letters "X," "Y," "Z," the idea being to make them a sort of compromise between the submarine and submersible, an attempt being made to combine the advantages and disadvantages of both types.

Submarine "X."

The submarine "X" was launched in December 1904, at Cherbourg, from the plans of M. Romazzotti, the designer of the "Morse" and "Naïade" types (Plate 28).

Her hull is built of steel and has a

Length of . . .	122 ft. 8 in.
Maximum diameter .	10 „ 2 „
Ordinary draught aft .	7 „ 6 „
Surface displacement .	168 tons.

Armament—1 torpedo tube and 4 sets of drop collars, two each side; five torpedoes carried.

Two benzoline engines are provided for propulsion on surface; these are each of 220 B.H.P., and drive two propellers, the speed obtained being about 11 knots.

For submerged work two electric motors are used furnished with electric energy from accumulators.

Submarine "Y."

At Toulon the submarine "Y" was laid down from the designs of M. Bertin and launched in the summer of 1905. This boat is larger than "X," having these dimensions:—

Length . . .	140 ft. 6 in.
Maximum diameter .	10 „ 6 „
Surface displacement .	213 tons.

1 propeller.
4 torpedo tubes.

The heavy oil internal-combustion engine has been designed by M. Bertin for both surface and submerged running; presumably

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PLATE 28.—*SUBMARINE "X."*

PLATE 29.—*SUBMARINE "Z."*

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storage for a considerable quantity of air or oxygen has therefore been provided for use when sealed down. No particulars of this engine are yet forthcoming, but it is understood considerable difficulties have been experienced with the designs.

Submarine "Z."

The designs of M. Maugas were accepted for submarine "Z," and she was built at Rochefort, being launched towards the end of 1904, of these dimensions:

Length . . .	135 ft. 6 in.
Maximum beam .	9 „ 8 „
Surface displacement .	200 tons.

A heavy oil motor is provided for surface work, and an electric motor worked off accumulators for submerged running of 190 E.H.P. This boat is supposed to have unusually good under-water lines, and therefore she was chosen to represent an ideal submarine as compared to the submersible. Her armament consists of two double torpedo tubes fixed in the bow, and four torpedoes are carried.

To give this boat more habitability, a flying bridge has been fitted, as shown on Plate 29.

"Guêpe" Class.

The chaotic policy of M. Pelletan in regard to submarine design reached its zenith when he decided to associate small submarines with the large offensive type for the inner line of harbour defence. These were to be of only 45 tons displacement, 60 ft. in length, 6½ ft. beam, smaller even than the "Gymnote," and built from the designs of a M. Petithomme; this type was to be known as the "Guêpe" class, and approval was given for ten of these boats to be constructed. A change of Ministry, however, came in and cancelled the order, with the exception of two that had been started at Cherbourg.

"Goubet III."

A small submarine is being constructed at Toulon for use in one of the battleships building; special appliances will be provided for hoisting the boat in and out in a seaway.

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The dimensions are:

Length	36·5 ft.
Maximum diameter . .	6·5 ft.
Surface displacement . .	21 tons.
E. motor of . . .	140 E.H.P.

If the experiments with this small boat are successful we may yet see the dream of M. Claude Goubet come true, and find all battleships and large armoured cruisers provided with a submarine or two.

"Sirène" Class (Submersible).

Having noted the French submarines proper, we now glance at their submersibles (Plate 30).

The "Sirène,"	"Silure,"
"Triton,"	"Espadon,"

were laid down at Cherbourg and launched mostly towards end of 1901. These boats are designed on the "Narval" principle of double hulls by M. Laubeuf, and have the following dimensions:

Length . .	111 ft. 6 in.
Beam . .	12 „ 4 „
Draught . .	5 „ 3 „

The displacement on surface is 155 tons and when submerged 200 tons. A triple-expansion steam-engine of 250 I.H.P. is provided with steam from a single boiler. The water in this is heated by an oil spray; for submerged propulsion two motors fitted tandem fashion are furnished with electrical energy from accumulators on the Laurent-Cely principle; these give a range of 25 miles at 7·5 knots.

The speed on the surface is 8 knots, the range being estimated at 500 miles with a speed of 7 knots. The crew number one officer and nine men.

The "Narval" took as much as twenty minutes to dive, whereas these boats take ten minutes; with a well-trained crew they are supposed to perform the operation in six minutes. The "Triton," in trials off Cherbourg, got the time down to six and a half minutes.

The armament consists of four 17·75-in. torpedoes carried in four sets of Drzewiecki collars.

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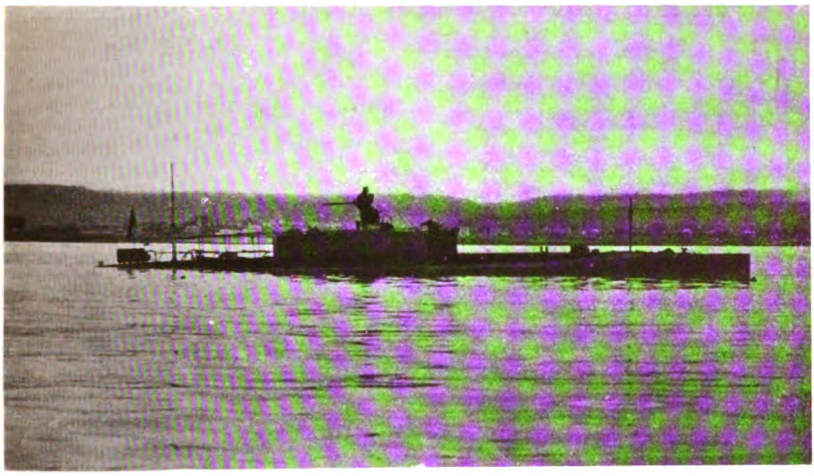

PLATE 30.—*SUBMERSIBLE "TRITON."*

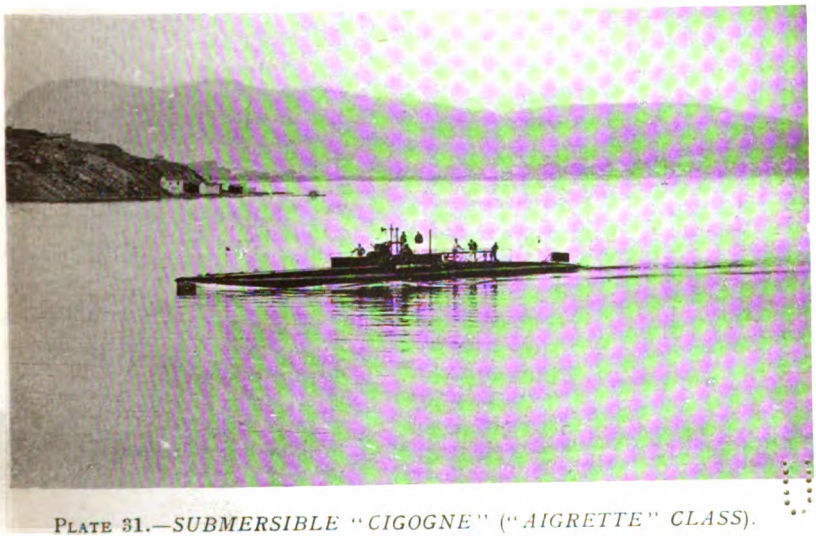

PLATE 31.—*SUBMERSIBLE "CIGOGNE" ("AIGRETTE" CLASS).*

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"Aigrette" and "Cigogne" (Submersibles).

The "Aigrette" is an improved "Sirène" (Plate 31). Thirteen of this type were ordered by M. de Lanessan in 1902, but a change of Ministry occurred, and M. Pelletan became Minister of Marine.

The original order was cancelled, and approval was given for only two of this type to be constructed from the designs of M. Laubeuf. The arrangements in these boats differ somewhat from the double hull of the "Narval" and the "Sirène" class, for instead of the outer hull encircling the inner, it is only built on the sides of the boat. This modification reduces the draught, and, by not having an open upper compartment, the seaworthiness of the boat when running on the surface is considerably improved. The dimensions are:

Length . . .	118 ft.
Maximum diameter .	13 „
Draught aft . .	8 „ 4 in.
Displacement on surface	175 tons.
„ submerged	220 tons.
Buoyancy . . .	22 per cent.

An internal-combustion motor of the Diesel type (Plate 78), of 185 H.P., is used for surface propulsion; this is supposed to give a speed of 9·5 knots, and the electric motor for submerged work, of 147 E.H.P., gives a speed of about 7 knots.

The time taken to trim for diving when all weights are on board is just over four minutes.

"Oméga" (Submersible.)

A few details of the "Oméga," laid down in January and launched in November of 1905, have been obtained. The boat is larger than any of her predecessors, having

Length . .	160 ft. 6 in.
Beam . .	13 „ 9 „
Draught . .	9 „
Surface displacement	301 tons

This is a very great increase in size, and makes these craft analogous to destroyers.

A Bertin petrol motor is provided of 330 H.P.; this type uses a heavy oil.

The speed on surface is expected to be 12 knots, and for

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submerged running electrical energy is provided from accumulators for working the motor; this gives a speed of 9 knots.

The armament consists of two torpedoes carried in Drzewiecki drop collars and two in bow torpedo tubes, placed one above the other. The boat will probably have a complement of two officers and eighteen men.

"Émeraude" Class (Submersible).

In October 1903 six submersibles, designed by M. Maugas, the designer of "Z" submarine, were laid down, the first three at Cherbourg and the others at Toulon. These were the

"Émeraude,"	"Saphir,"
"Opale,"	"Topaze,"
"Rubis,"	"Turquoise."

They have a double hull on the "Narval" principle, and are of the following dimensions:

Length . .	147·64 ft.
Beam . .	13·12 „
Surface displacement	392 tons.

Two heavy oil motors of 240 H.P. are provided for driving two propellers when running on the surface, and it is anticipated a speed of 12 to 13 knots will be obtained.

Also electric accumulators and motors are provided for submerged work, and the armament consists of four torpedoes carried in Drzewiecki drop collars.

"Circé" Class (Submersible.)

Orders in October 1904 were placed for two boats of a modified "Emeraude" design to be known as the "Circé"* type. They were each to displace 351 tons; length about 180 ft.; beam 12·8 ft.; 600 H.P.; estimated speed on surface to be 13 knots. The cost of the two was to be about £145,600.

In October of 1906 two submersibles of 400 tons were also ordered to a similar design, and it is anticipated these large boats will take from twelve to eighteen months to complete.

The disadvantage of the submersible in not at all times being

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* "Calypso" and "Circé," from designs of M. Laubeuf.

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ready to dive quickly, has led to two schools being formed in France. The Toulon school advocated the submarine, and the Cherbourg school tended to favour the submersible.*

A Commission, under Admiral Philibert, was appointed in 1905 to determine the strong and weak points of the most perfected submarine and submersible constructed. The "Aigrette" was chosen to represent the submersible class and the "Z" the submarine. The comparative trials were carried out at Cherbourg and terminated within a week, with the result that the superiority of the submersible over the submarine for all practical sea-going work was most clearly shown.

The "Aigrette," with much more beam and better distributed weights, showed herself to be much the better sea-boat of the two, and was the drier, although she has no bridge, and she answers her helm well, while her habitability is of course far better than that of the submarine, as the men can come up and breathe fresh air in perfect safety; "Z," on the contrary, did not rise to the sea, and laboured a good deal, this being due, it is supposed, to her four torpedo-tubes weighing her down forward; moreover, she does not steer well; while the high bridge with which she has been fitted for navigating purposes when moving on the surface, has the disadvantage of rendering her visible at a distance.

"Z" ought to have realised a speed of 11 knots on the surface, but she only made 8·3 knots; when submerged she only made 4·1 knots, and it is not believed to be possible to increase speed to 6 knots, while the stipulated speed was 7·6 knots. The "Aigrette" made 8·7 knots on the surface, instead of 9·2 knots promised; when submerged she made 6·3 knots instead of the stipulated 6·7 knots. While "Z" rolled heavily and her crew experienced much discomfort, the roll of the "Aigrette" did not exceed 12°. What caused comment during the trials was the time taken when diving; it was fully expected that "Z" would have dived in much less time than the "Aigrette," as she is an improved and larger "Farfadet," and the "Farfadet" is able to dive in 90 seconds, whilst, according to calculations, 5 minutes is allowed for the "Aigrette" to dive. Three trials were made under practical conditions at sea, with the machinery for running on the surface at work.

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* From *Le Yacht*, *Le Moniteur de la Flotte*, *Le Temps*, etc.

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The result of the three trials were as follows:—

"Aigrette"	. .	4	min. 30	sec.
		4	„ 14	„
		5	„ 50	„
"Z"	. . .	5	„ 30	„
		4	„ 30	„
		10	„	

These trials seem clearly to show that the submersible alone presents the necessary qualities for all prolonged navigation at sea; this does not necessarily involve the complete abandonment of the submarine, but it must be adapted to a certain rôle, and more must not be expected from it than it can perform. The submersible is the engine of offence, but the submarine can render useful service for coast defence, that is, over a limited field of action. The submarine costs much less than the submersible; it will therefore be advisable to use it for defensive purposes.

Another result of the trial has been to show that "Z," which is a large "Lutin," the plan for the two vessels being by the same designer, has not gained anything by her increased dimensions, whilst the "Aigrette," which is an improved "Narval," has, on the contrary, gained much. The Committee are of opinion that the submersible of the future should have a displacement of 400 tons, and that the useful displacement of the submarine should not exceed 100 tons.

Since these submarine versus submersible trials held at Cherbourg, an official order has gone forth to develop the submersible of large tonnage as being more suitable to the requirements of the French Navy for offensive defence. At the same time a limited number of submarines may be provided for purely defensive purposes.

To assist in the evolution of these vessels a permanent Submarine Committee has been appointed. In officially announcing this step the Minister of Marine says:—

"It is important that studies in connection with the submarine question should be centralised, and the interest rightly attached to the development and perfecting of an engine destined to effect a change in the conditions of naval warfare makes it desirable to create a distinct branch exclusively charged with examining the conditions and needs of submarine navigation.

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"As far as the working of them is concerned," continues the report, "boats constructed to carry torpedoes under water are quite distinct from those made to act on the surface, and the machinery and appliances necessary for the submarine require a separate study, more especially as regards the motor, diving rudder, and the instruments of vision; this study can only be followed by officers who specially devote themselves to it.

"As regards the employment and management of submarines, it is essential that all information obtained should be collected and considered by a central committee.

"These small vessels have hitherto been attached to three of the naval ports, and the officers in command, by daily practice with them, have gained much useful experience; but the information thus obtained has not been centralised in any way, and it has happened that some difficulty under investigation at one of these ports had been already solved elsewhere.

"It is particularly necessary, in the case of submarines, to establish constant intercommunication between the conception of the engineer and the practical experience of the officer in command. Such collaboration has, by the force of things, already been partly established, and it is to this we owe the great progress we have made, for which we are so much envied."

The Minister, after having specified that the term "submarine" is to include also the "submersible" class, goes on to say:—"The task of the Committee will be to centralise all information relative to submarines, both as regards the plans of such vessels, their machinery, reports of inspection, etc. New plans will be submitted to it, but it will not be charged with the duty of itself proposing new plans. To solve such novel and complex problems as those raised by the submarine, nothing is more necessary than individual encouragement to men of merit, whether naval architects or scientists, or connected with private industry; and that the members of the Committee may be exempt from all party bias, it seems to me advisable that they should confine themselves to examining plans and projects originating outside their body. I have therefore not added to the Committee any of the eminent engineers, the designers of our best submarines, who will, it is to be hoped, continue their labours for us, and excel their previous designs, being left to their own initiative."

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In 1906 the Budget Commission recommended the construction of twenty submersibles of 398 tons, the length of each to be 167·72 ft., beam 16·3 ft., draught on surface 10·24 ft., with two propellers. For motive power on surface steam has once more been suggested for these boats, but before a decision is arrived at it is understood exhaustive trials will first be carried out in the older boats with the latest types of light and heavy oil internal-combustion motors.

For submerged running electrical energy will as usual be furnished from accumulators. These boats are all to be of the improved "Circé" type and are to be completed by 1908.

Some interesting experiments were carried out early in 1906 to ascertain if a port in a condition of close blockade could receive despatches from outside by the employment of submarine boats. The "Gustave Zédé," "Grondin," and "Souffleur" were used for this test. The watching vessels consisted of gunboats, destroyers, and torpedo-boats; during the whole operations the submarines had no difficulty in evading these craft. If an old boat, as the "Gustave Zédé," can come successfully through these trials, what will the modern French submersible of 700–800 tons be capable of doing when commanded by officers whose courage and resource is beyond dispute?

Submersibles of 800 tons Displacement.

Of the twenty submarines approved for 1906 only sixteen have been put on the stocks,* as the Minister of Marine has had designs for a larger boat under consideration.

It has now been definitely decided to construct two large boats at Cherbourg from the designs of MM. Hulter and Radiguet, one at Toulon from designs of M. Maurice, and one at Rochefort from the design of M. Bourdette.

All these designers are naval engineers, and they guarantee to produce submersibles of 800 tons displacement and 227 ft. in length. The speed on surface to be 15 knots, with 10 knots submerged. The range to be 2500 miles without taking in fresh oil.

For the present France has given up the construction of the small submarine in order to develop these large 800-ton submersibles, which it is anticipated can be navigated in almost any weather.

---

* Namely, three at Cherbourg, seven at Rochefort, and six at Toulon.

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The engine question for these large boats is by no means yet settled. Experiments with steam, heavy oil and petrol are still being pursued with determination, but nothing definite is decided. The motive power for submerged work will be the usual electric motor fed from a battery of accumulator cells.

On the conclusion of the French grand manœuvres of 1906, the Commander-in-chief, Vice-Admiral Fournier, in an order of the day pointed out as follows :—

"The operations of the fleet before Bizerta, Toulon, and Marseilles showed that the arm *par excellence* for the defence of harbours is the torpedo in all its different forms, but above all in the employment of torpedo-boats for night attacks and submarines by day.

"The following figures show the damage that the torpedo-boats and submarines could effect against a fleet attempting these operations. Five ships would have been placed *hors de combat* before Bizerta, five before Toulon, sixteen before Marseilles in the first attack and twenty-five in the second attack." The Vice-Admiral further remarked, "One cannot, then, too often point out, with a patriotic and legitimate satisfaction to our country, that the ægis of the sea-fronts of France in the future is a numerous flotilla of torpedo-boats and submarines covering the harbours and the points of the coast accessible to the enemy's attacks, in advance even of the action of the coast batteries.

"It is not the arm evidently for the conquest of the sea, which remains incontestably with the big ship, but it is the one which will most surely destroy every victorious fleet wishing to crown its success by finally attacking the enemy's post. From this point of view, the coast operations of our fleet have perfected to its profit the lessons of facts at the critical point, where the English fleet had left them at the conclusion of the brilliant manœuvres of mobilisation and operations on the high sea carried out last month."

In conclusion, Admiral Fournier paid a special tribute to the high training and enthusiasm of the first flotilla of submarines of the Mediterranean fleet, their extremely successful attacks on the fleet before Marseilles. Thanks to the skilful and bold use of their periscope, their degree of invisibility was such that they were able to approach with almost certainty to within launching distance of their torpedoes without being seen.

Again, at a banquet given to Admiral Fournier, he stated that the submarines had torpedoed his flagship no less than eight times and

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prevented him from carrying out his previously prepared plans. The Commander-in-chief also remarked that he considered these under-water vessels realised all that was expected of them and that they had revolutionised naval warfare.

In concluding the remarks on French submarines a word may be said on the value of this class of war-vessel to our neighbours. At the present time the problems France is faced with have completely changed from the days in which the "Guerre de course" was the war-cry.

Thanks to M. Pelletan, the socialistic tendency in the French dockyards has been unduly fostered. This largely affects new construction, making it of longer duration and so more costly. Therefore it is extremely doubtful if the ambitious programme of six 18,000-ton battleships authorised in 1906 will be completed in reasonable time.

If France is to maintain her sea-power, battleships are necessary to prevent other nations leaving her far behind. However, it must not be overlooked that there is still a great feeling of opposition in that country against costly battleships, and this will not be lessened by the recent misfortunes that have resulted in the navy losing the cruisers "Sully," off Cochin China, February 1905, "Jean Bart," west coast of Africa, February 1906; and in March 1907 the battleship "Iéna" became an appalling wreck, whilst lying in dry dock at Toulon, from internal explosions believed to be caused by defective powder in her magazines. Therefore at any time French politicians may force their Government to admit that they are unable to compete with other nations, as America, Japan, and Germany, in building mammoth battleships. If such a day should come, then reliance must be placed on the lead that has been obtained with sub-aqueous boats.* All the high engineering skill and capabilities that France is so rich in will no doubt be placed at their country's disposal for building up a complete torpedo defence of her coast-lines.

* Admiral Fournier has, in his capacity of Naval Inspector-General, recently addressed a noteworthy order of the day to the Channel submarine flotilla before his retirement. After congratulating that branch of the service on the success of its recent manœuvres, and encouraging both officers and men to maintain their faith in the submarine, the Admiral said:—

"It is principally from that arm that France ought to expect her maritime enfranchisement. It will in future be the main element of her power and her security, owing to the comparative strength of her financial resources, and to her privileged geographical position in European waters."—*Times*, May 14, 1907.

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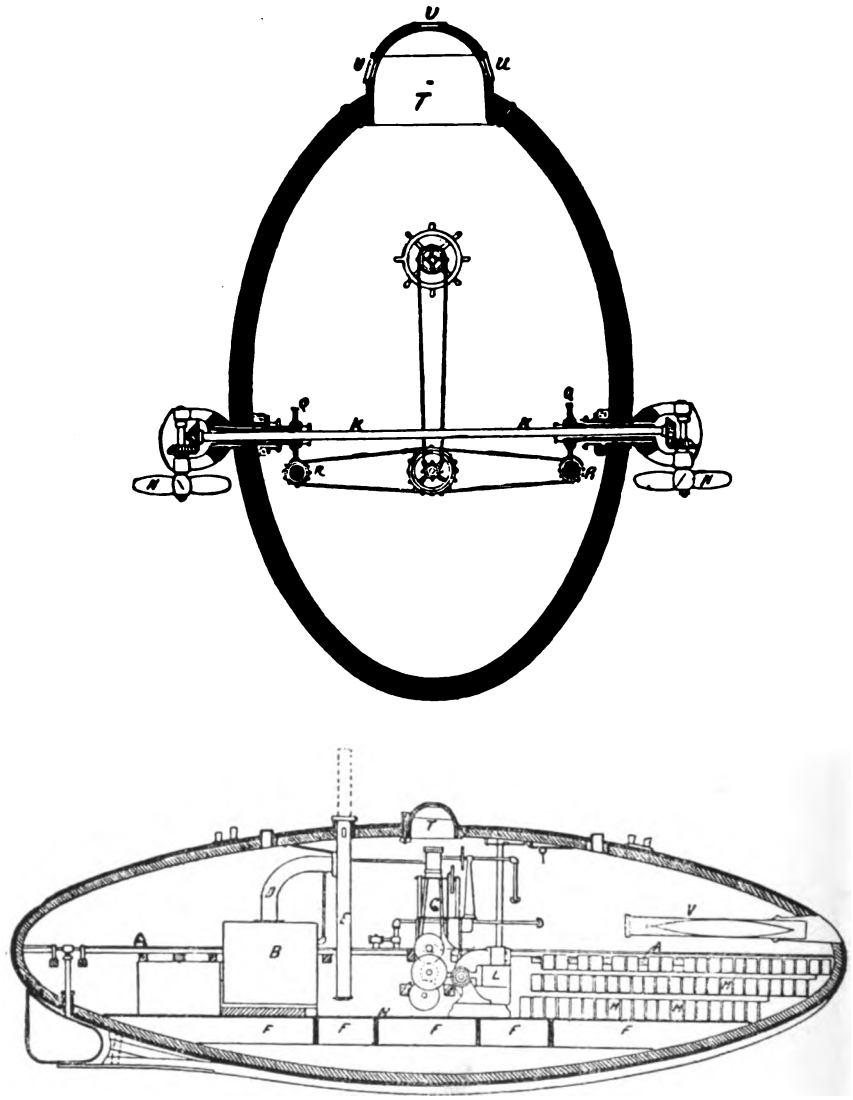

FIG. 23.—*BAKER'S SUBMARINE BOAT.*

A.—Upper Platform Deck.
B.—Boiler.
C.—Main Engines.
D.—Exhaust Pipe leading into Funnel.
E.—Funnel.
F.—Water Ballast Tanks.
H.—Lower Platform Deck.
K.—Main Shafting.
L.—Dynamo.
M.—Electric Storage Battery.
N.—Adjustable Propelle s.
Q.R.—Gearing for Operating Propellers.
T.—Conning Tower.
U.—Scuttles for Admitting Light.
V.—Torpedo Tube.

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CHAPTER XI.

AMERICAN SUBMARINES.

THE following is an extract from the United States Navy Appropriation Bill for 1893–94 under the heading of "Ordnance Bureau."

"Submarine Torpedo-boat.—For building a submarine torpedo-boat and conducting experiments therewith 200,000 dollars to be taken from the balances of appropriations on hand 1st July, 1893, to the credit of armour and armament of vessels heretofore authorised."

The object of making this provision was to induce inventors to turn their attention in the direction of the submarine boat, with the understanding that the best design sent in was to get the order.

The Bureau of Ordnance prepared advertisements, and Mr. Whitney, then Secretary of the Navy, caused them to be circulated in the United States.

These invited plans and specifications for a submarine boat which could attack an enemy's ship under water. The standard of requirements which inventors of submarines were requested to try and meet were placed in the following order: (1) safety; (2) facility and certainty of action when submerged; (3) speed when running on the surface; (4) speed when submerged; (5) endurance, both submerged and on the surface; (6) offensive power; (7) stability; (8) visibility of object to be attacked.

That the Board was doubtful that these requirements would be met in their entirety was shown in their recommendation, which read: "Bidders are at liberty to modify their proposals as they may think proper in any of the qualities mentioned herein, always excepting qualities of workmanship and materials used in the construction of the hull, engines power generators, and other mechanism. As the department does not define the means by which results ought to be

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attained, it will accept no responsibility as to the efficiency of the methods proposed to be used.*

Several designs were sent in, which took their names from the engineers who submitted them.

The chief of which, in alphabetical order, were:

1. The Baker boat.
2. The Holland boat.
3. The Lake boat.

We first propose to consider the boat built for Mr. Baker, of Chicago, on the Detroit River by the Detroit Dry Dock Company.

The "Baker" Boat.

The construction took nearly two years, and as Detroit was an unsuitable place for trials, it was necessary, on completion, to take the submarine to Chicago.

The boat was cigar-shaped (Fig. 23),

40 ft. in length, and
14 „ in beam.

The hull being constructed of the best seasoned oak 6 in. in thickness, covered with special waterproof cloth and capable of withstanding a pressure of 75 lbs. to the square inch. The displacement was about 75 tons, and divided thus—hull, 20 tons; ballast, 30 tons; storage-battery cells, 10 tons; engine, boiler, and gearing, 8 tons; motor, 3 tons; leaving 4 tons for reserve buoyancy; when at normal draught about 2 ft. of the crown of the hull remained above water.

The principal feature in which this invention differed from previous designs was that the side screws were so geared as to regulate the depth of submersion as well as to propel the boat. The propelling power was provided in duplicate, an electric and steam plant, the former for running under water and the latter for surface propulsion, the steam-engine being so arranged that it could be used to drive a dynamo for generating electricity to charge the storage batteries.

* Extract from a paper read before the members of the Institute of Naval Architects, entitled "Safe Submarine Vessels, and the Future of the Art," by Mr. Simon Lake, March 1907.

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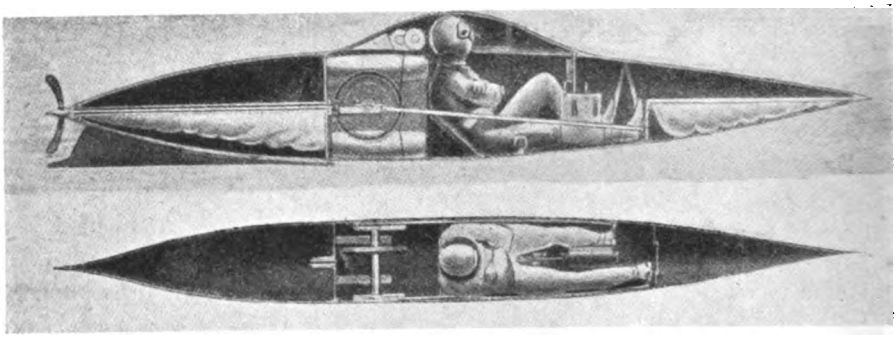

PLATE 32.—*AMERICAN HOLLAND "No. 1."*

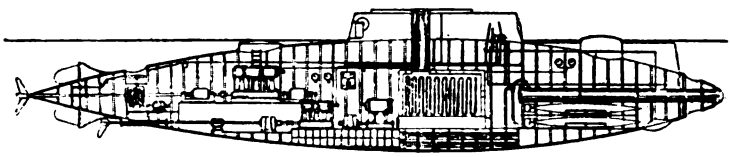

FIG. 24.—*THE "PLUNGER."*

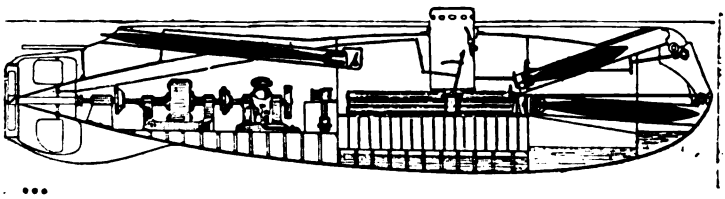

FIG. 25.—*HOLLAND "No. 8."*

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On top of the vessel a small conning-tower was built, through which the crew reached the interior; glass scuttles were provided in the sides of the tower for conning purposes, etc., and water could be taken into the ballast-tanks for decreasing the buoyancy; also suitable arrangements were provided for ejecting it to diminish the displacement when necessary to raise the vessel. Air was sucked down by means of electric fans placed at the bottom of tubes which led to the surface.

During the trials two men remained in the boat when under water for one hour and forty-five minutes. This submarine failed, owing to the difficulty of keeping an even depth-line when running submerged. The speed obtained was fairly satisfactory, and the hull stood a depth of 16 ft. without leakage.

If Mr. Baker had provided his boat with a propelling system quite distinct from the diving arrangements, no doubt the boat would have been fairly successful, as all the details were carefully worked out, and can be seen in diagram.

The Holland Submarine Boat.*

The legal side of the Navy department naturally required a guarantee of fulfilment of promise, which apparently upset some of the inventors, as finally the order was given for a Holland boat to be constructed for the Government. This design has now been adopted as the embryo submarine boat by many naval Powers of the present day. The type has been worked up from Mr. Holland's early experiments in the seventies of last century by much continuous effort coupled with good skill as a designer; gradual improvements have led to complete success in the design of a submarine boat.

The inventor has come to the front in one of the most strenuous efforts ever made by an engineer to get new ideas recognised even by his own countrymen, and only during the last few years has he been in any way successful. In a later chapter a brief history of the Whitehead torpedo is given. Mr. Holland took this for his model, and, to quote his own words, says: "The submarine boat is a small ship on the model of the Whitehead torpedo, subject to none of its limitations, improving on all its special qualities, excepting speed,

* Most of the information and photographs for this chapter were kindly supplied by the Holland Electric Boat Co.

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for which it substitutes incomparably greater endurance. It is not like other small vessels, compelled to select for its antagonist a vessel of about its own or inferior power; the larger and more powerful its mark, the better its opportunity."

The Holland "No. 1" was constructed in the year 1875 (Plate 32).

Dimensions:

Length . .	16 ft
Beam . .	20 in.
Depth . .	2 ft.

The single operator sat down, with his head in a diver's helmet, and drove the boat with his feet, a pedal device giving rotatory motion to a propeller in the stern, under which was placed the vertical rudder; the fore and after compartments were used for ballast and as a storage for compressed air.

Several boats were built of an experimental nature, which were useful in demonstrating certain details of design; in one an internal-combustion engine using gasolene (the American name for petrol was first tried for surface propulsion. This turned out quite a success. Many details in regard to the position of the rudders for control in the vertical and horizontal plane were worked out.

The design reached Holland "No. 7" when it was submitted to the Naval Bureau and accepted (Fig. 24). Many obstacles were placed in the inventor's path, in connection with guarantees, by change of administration, etc., and it was not until March 13, 1895, that the contract was actually signed. During this year the Holland Boat Company was formed to develop the invention.

Still further delays occurred before the drawings were finally approved, and it was not until June 23, 1896, that the boat's keel was laid down. On August 27 of the following year she was launched under the name of "Plunger," with these dimensions:

Length . . .	85 ft.
Maximum diameter .	11½ „
Displacement on surface	140 tons.
Displacement submerged	165 „

The inventor was obliged to alter his original proposals and adopt petroleum-burning boilers and two sets of triple-expansion engines; these were designed to develop 1500 H.P. and work two propellers. The estimated speed on the surface was to be 14 knots. Electric

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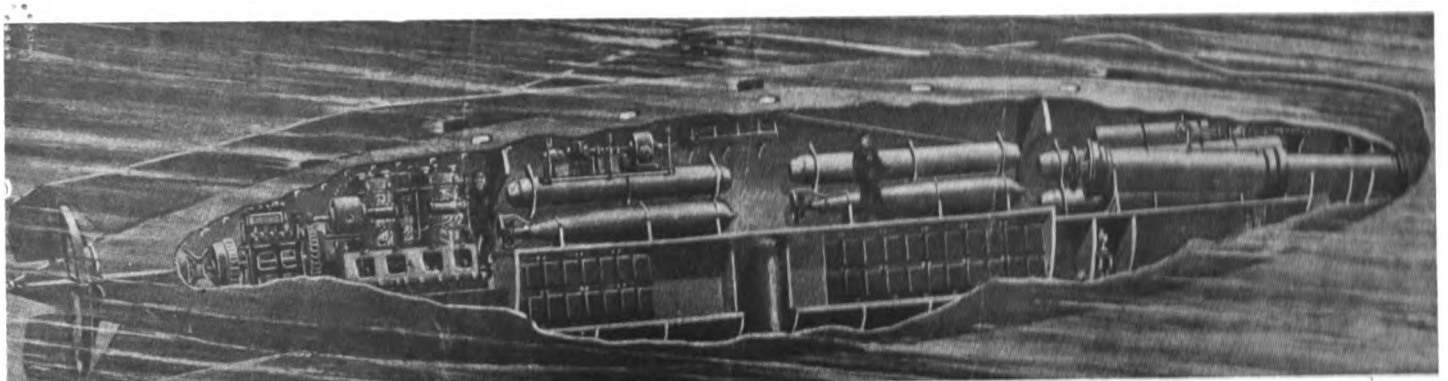

PLATE 33.—*THE "HOLLAND SUBMARINE" UNDER WATER.*

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accumulators were to be used for submerged work and a speed of 8 knots was expected. Down-haul screws were provided to assist the horizontal rudders when submerging. The enormous steam power that the authorities attempted to obtain made the boat uninhabitable on account of the high temperature; from this and other causes the completion of the "Plunger" was abandoned for some considerable time.

While the "Plunger" was being constructed for the U.S. Government the same company designed the Holland "No. 8," and built her privately (Fig. 25).

Length . . .	53 ft. 10 in.
Diameter . . .	10 ft. 3 in.
Displacement on surface	75 tons.
Otto gasolene engine .	50 H.P.

Electric motor fed by sixty cells with a capacity of 1500 ampère hours at a 4-hour rate of discharge.

The armament consisted of

1 bow tube.
1 pneumatic dynamite gun placed in the bow.
Speed on surface with gasolene engine 7 knots.
Speed on surface with electric motor 6 knots.
Speed when submerged with electric motor 5½ knots.

The boat was an undoubted success, and Mr. Holland placed her unreservedly at the disposal of the United States authorities, who, after exhaustive experiments, recommended that this submarine should be bought and added to the United States Navy. This was finally approved, and the Government paid £30,000 for the vessel.

A general description of a Holland* boat, which, with slight modifications, is the same for all the class, is as follows:—

The hulls are pointed at each end with the maximum diameter of 11 ft. 10 in. towards centre, length 63 ft. 4 in. To trim for diving, water is admitted into the main ballast, auxiliary ballast, fore and aft trimming-tanks. The main ballast-tank is filled right up. The auxiliary ballast varies with the number of men on board, and stores, petrol, etc., this usually is one-half to three-fourths

* Also see first British Holland, Chapter XII.

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full. The trimming-tanks are roughly half-full of water; this can be blown from right forward to right aft, or *vice versa*, so as to bring the boat into a horizontal position; a bubble travelling in an ordinary gauge-glass shows the captain how the boat is trimmed, either by bow or stern or, if in centre, quite horizontal. This is the position for obtaining the best diving results with the superstructure well awash, the level of the water coming just under the conning-tower scuttles. The reserve of buoyancy due to the conning-tower when in this position is about 300 lbs.; the boat can be easily controlled by the horizontal diving rudders when travelling at a speed of 5 to 6 knots (Plate 33). This is a different system from that of the Nordenfelt or Goubet boats.

Emergence in the Holland is obtained:—

1. By stopping; then the boat rises, due to reserve of buoyancy.

2. When under speed, by putting the helm hard up. This action of the rudder, in addition to the reserve of buoyancy, causes the boat to come to the surface quickly.

3. Blowing out the main ballast-tanks with compressed air carried in air-bottles stored at 2000-lb. pressure. This is reduced to a 50 and 10 lb service for the ordinary work of blowing-tanks.

At first air-engines were used for working the horizontal and vertical rudders, but in later boats these have been replaced by hand power transmitted by rods and gearing to rudders. This is considered preferable to any automatic arrangements, which are always liable to fail when most required.

For surface propulsion, power is transmitted from a four-cylinder Otto gasolene engine * of 160 H.P., through gearing of 1 to 1·9, to the propeller. Each cylinder can be worked independently of the others. The gasolene engine, besides providing power for surface running, can work an air-pump for filling up the air-reservoirs, and can also run the motor as a dynamo for charging up the electric battery.

Compressed air is carried in air-flasks of about 4 ft. long by 7 in. diameter, these are joined up in groups and charged to a pressure of 2000 lbs. per square inch, the whole number having a capacity of 42 cubic ft. This is in volume a square mile of uncompressed air, or would last nine people nine weeks without a fresh supply.

* See Chapter XVII, on Motive Power on Surface.

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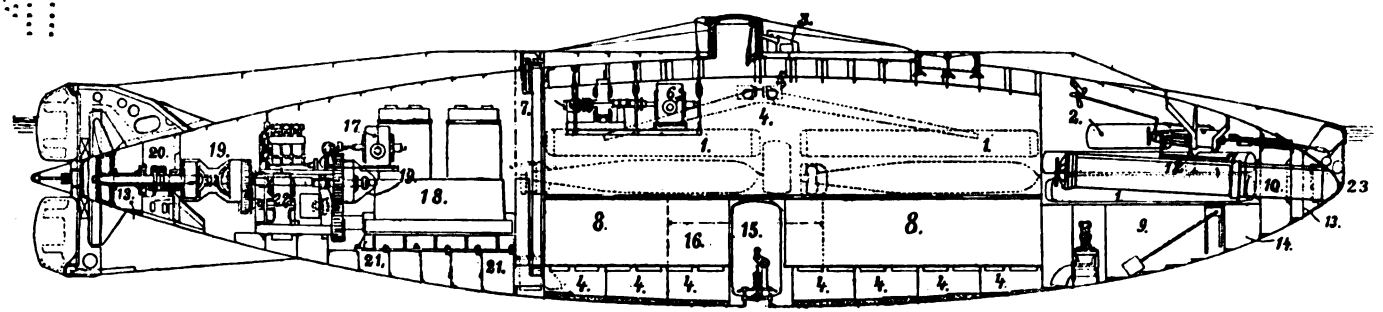

FIG. 26.—*HOLLAND "No. 9."*

1.—2,000 lb. Air Flask.
2.—Compensating Tank for Torpedo.
3.—Compass.
4.—Main Ballast Tank.
5.—Vents to Main Ballast Tank.
6.—Auxiliary Motor Bilge Pump.
7.—Ventilator.
8.—Electric Storage Batteries.
9.—Gasolene Tank.
10.—Torpedo Tube.
11.—Torpedo Compensating Tank.
12.—2,000 lb. Air Flask.
13.—Fore Trimming Tank and After Trimming Tank.
14.—Water round Torpedo Tank.
15.—Circular Buoyancy Tank.
16.—Auxiliary Ballast Tank.
17.—Main Bilge Pump.
18.—4-Cylinder Gasolene Engine.
19.—Clutch.
20.—Thrust Bearing.
21.—Water Ballast Tanks.
22.—Electric Motor.
23.—Bow Cap.

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The compressed air is used for several purposes :—

1. To blow the water ballast, taken in when trimming for diving, out of the tanks.

2. To charge torpedoes.

3. To fire torpedoes.

4. By its leakage the volume of air in the boat is diluted* and, by being augmented with a fresh supply, lasts longer for breathing purposes; also a slight air-pressure inside the boat prevents water leaking from any ill-fitting gland, etc.

For motive power when submerged, a shunt-motor of 70 E.H.P. is furnished with energy from electric storage batteries having a combined capacity of 1840 ampère hours.

The motor is provided with a clutch for connecting to propeller shaft; the gasolene engine cannot be reversed, therefore the motor has to be clutched in for going astern, the gas-engine being first unclutched from the propeller shaft.

Number and description of the crew:

1 officer and helmsman in command.
1 helmsman at diving wheel.
1 engineer.
1 electrician.
1 gunner.
1 machinist and oiler.
1 man at air and water valves.

In June 1900 Congress authorised the construction of six boats; a contract for this order was signed on August 25th of the same year between the Secretary of the United States Navy and the Holland Boat Company (Fig. 26).

The names given to these boats were as follows :—

1. "Adder."
2. "Moccasin."
3. "Grampus."
4. "Pike."
5. "Porpoise."
6. "Shark."

Numbers 1, 2, 5 and 6 were laid down in the Crescent shipyard of Lewis Nixon, Elizabeth Port, New Jersey; 3 and 4 were laid down in the construction yard of the Union Ironworks, San Francisco, California.

The "Adder" and "Moccasin" were launched in July and

* Chapter XX, on Fumes.

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August of 1901, and we find them in November 1902 carrying out a series of trials in Peconic Bay before Captain Train, the president of the Board of Instruction and Survey, who represented the U.S. Government. The boats exceeded their contract speed, and did over 8 knots on the surface with the 160-H.P. gasolene engine. The submerged runs were instructive, torpedoes being fired with fair accuracy, and one long run was made by the "Adder" with only her periscope showing. In this trip she struck the bottom in 22 ft. of water, with a 10° inclination, by the nose, which she buried in the soft mud. The electric motor was stopped, and owing to the reserve of buoyancy, some 300 lbs., she should have come to the surface, but the mud held her until Captain Cable redistributed the crew, which on these occasions are used as movable ballast. By sending men aft he brought the boat horizontal; then by blowing the ballast-tanks at the same time she rose to the surface; and on refilling the tanks Captain Cable continued the long submerged run, doing in all about 15 miles under water. The speeds of the two boats compared were:—

	Light.	Awash.	Submerged.
"Adder" . .	8·732	8·12	7·08 knots.
"Moccasin" .	8·416	7·898	7·244 knots.

Both submarines were run under all four cylinders of the gasolene engines, the "Adder's" run being part of the 12-hour endurance test. The following average speeds were made over a distance of 10 nautical miles:—

"Adder" . 8·86 knots.
"Moccasin" 8·5 „ .

The Board came to the conclusion that these trials in calm water were highly satisfactory, but considered the boats, to give real proof of their value, ought to have an endurance trial in the open sea. The performances witnessed showed how necessary it was to train the officers and crew in the handling of these crafts.

Some days later the "Adder" and "Moccasin" were taken in tow by the gunboat "Peoria" with a view to carry out more trials, as recommended by the Board, and when in bad weather off Cape Henry, Virginia, the towing hawser snapped. The "Peoria" reached the submarines as they were lying close together and bumping into one another. A man courageously swam to the boats and, with great risk to himself, climbed up the side of the "Adder" and

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A UNITED STATES HOLLAND RUNNING AT FULL SPEED ON SURFACE.

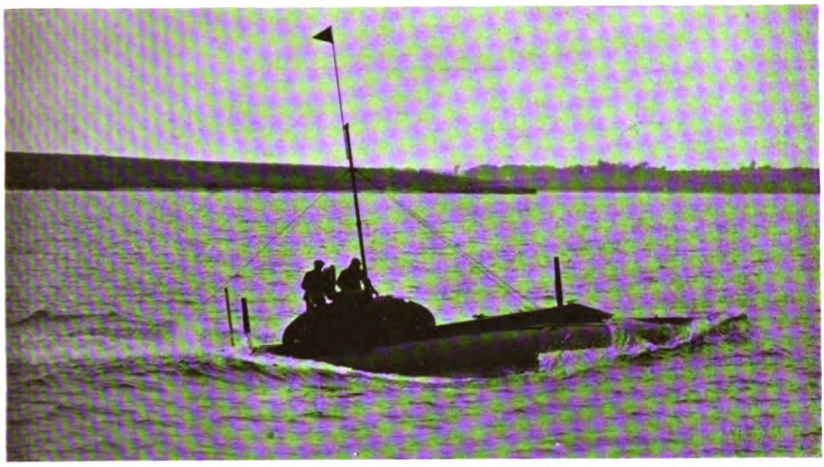

PLATE 34.—"*BROADSIDE VIEW.*"

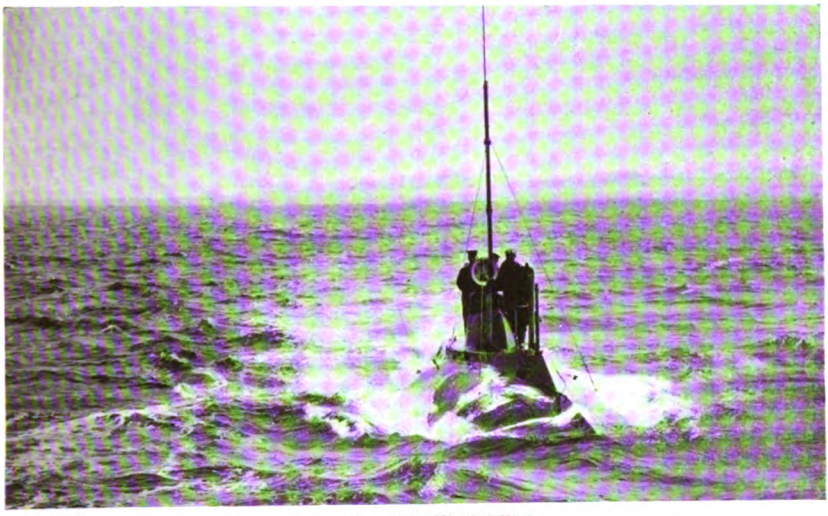

PLATE 35.—"*BOW VIEW.*"

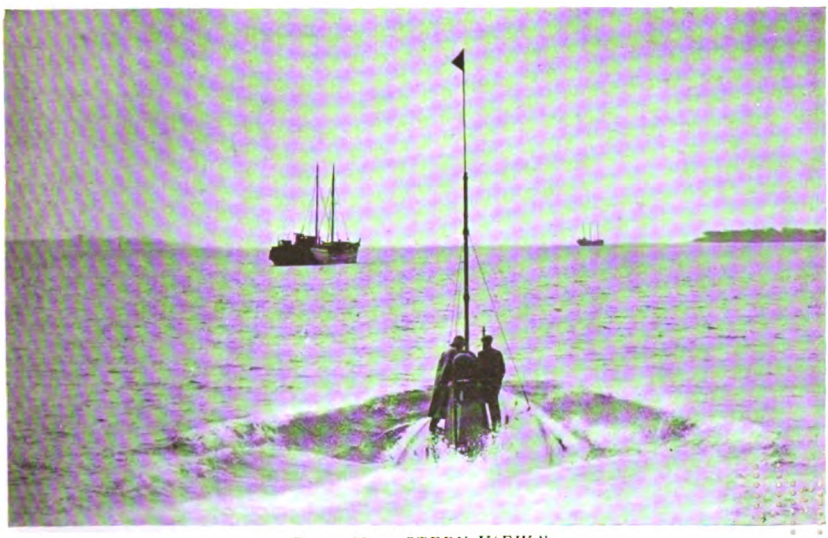

PLATE 36.—"*STERN VIEW.*"

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attached a tow-line. It was, however, found impossible to tow two boats at that time, and oil had no apparent effect upon the water, which was very rough, breaking over the boats and driving them in towards the beach. Shortly afterwards the towing hawser again parted, but by this time the boats were getting close inshore, and finally the "Moccasin" drifted upon the beach, where the work of salvage was undertaken at once. The "Peoria" was able to tow the "Adder" into Hampton Roads, where she was found to have a good deal of water in her, and her storage batteries in bad condition.

The "Grampus" and "Pike" were launched in July 1902 and January 1903 respectively, and a few months later carried out their official trials in San Francisco Bay; these occupied eleven days and were conducted by a Board of naval officers. A few details of these performances are of general interest.

The first trial was over a 10-mile (nautical) course in light surface trim*:—

	"Pike," April 6, 1903.	"Grampus," April 10, 1903.
Average revolutions	230·77 per min.	227·7 per min.
Cylinders in use	4	4
Mean speed of vessel	8·55 knots	8·47 knots.
Distance run	10·69 „	10·59 „

The results of a submerged run over a 2-mile (nautical) course were:—

	"Pike," April 6, 1903.	"Grampus," April 7, 1903.
Total revolutions observed during the run	2,840	2,733
Mean revolutions made	173·52 per min.	173·52 per min.
Speed per hour	7·14 knots	7·27 knots.
Battery	115·25 volts.	115 volts.
Load	500 ampères	500 ampères.
Depth of immersion	12 ft.	12 ft.
Distance run	1·95 knots	1·91 knots.

Lots were then thrown and the "Pike" was selected to represent the "Grampus" and herself in making a three hours' endurance trial, submerged.

* Tables taken from the *Journal of the American Society of Naval Engineers.*

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"PIKE."*

April 9, 1903.

Time.	Counter-reading.	Time on Surface. For Observation. Min.	Sec.	Revolutions per Minute.	Volts.	Ampères.
A.M.						
10.39.30	70,000	..		..	115	500
10.49.30	71,702	..		170·2	115·25	500
10.59.30	73,412	2	14	171	115·5	490
11.09.30	75,126	5	21	171·4	115·25	495
11.19.30	76,840	..		171·4	115	490
11.29.30	78,554	0	59	171·4	115	485
11.39.30	80,266	..		171·2	114·5	495
11.49.30	81,976	1	14	171	114	495
11.59.30	83,687	..		171·1	113·75	495
P.M.						
12.09.30	85,397	3	59	171	112·75	500
12.19.30	87,109	4	26	171·2	112·75	500
12.29.30	88,811	0	43	170·2	112	500
12.39.30	90,515	..		170·4	111·5	500
12.49.30	92,215	1	10	170	111	495
12.59.30	93,912	2	30	169·7	110	495
1.09.30	95,601	2	45	168·9	109·75	495
1.19.30	97,294	1	0	169·3	109	500
1.29.30	98,988	2	0	169·4	108	510
1.39.30	100,679	..		169·1	106·75	525

Total time on surface for observation .	28 min. 21 sec.
Mean revolutions	170·44 per min.
Mean speed of vessel . . .	7·07 knots.
Distance run	21·21 „

These results were considered very satisfactory. The actual time taken to dive with main ballast blown and other tanks full is about 4 min. To form a correct estimate of rapidity of any submarine diving it must be remembered that the time varies with amount of water in tanks; 29 min. is a maximum, with everything empty, in the Holland type.

* Table taken from the *Journal of the American Society of Naval Engineers.*

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The following three boats took:

"Adder,"	from light condition	.	29 min.
"Moccasin"	„ „	.	25 „
"Pike"	„ „	.	15 „

When trimmed for diving, to dip the boat under the surface takes only a few seconds.

The official trials of the

"Porpoise," "Plunger," "Shark,"

took place in Peconic Bay, Long Island, May 13–21, 1903.

Each boat was standardised in three conditions—light, awash, and submerged. After standardisation the boats had to make the following runs:—

1. Ten miles* in the light condition, under the gasolene engine, at a speed of at least 8 knots.

2. Ten miles in the awash condition, under the gasolene engine, at a speed of at least 7 knots.

3. Two miles submerged, under the electric motor, firing a torpedo at a target at the end of the run.

One boat was required to make a run of twelve hours, under the gasolene engine, at a speed of at least 8 knots. This being accomplished successfully, all the boats were to be considered satisfactory in this respect; also one boat was to make a run submerged, under the motor, for three hours at a speed of at least 7 knots. This being accomplished, all the boats were to be considered satisfactory in this respect.

The trials were successful and the boats duly accepted by the Government. Since passing into the United States Navy the submarines have been continually employed, and though some narrow shaves have been run during manœuvres no accidents attended with loss of life have occurred.

The "Porpoise" had perhaps the most interesting experience a modern submarine has yet undergone. Whilst submerging off Breton Reef, near Newport, the captain of the boat took her to a depth of 20 ft. and intended to attack the "Stiletto." Owing to some defect in the kingston valves more water than intended was taken into the tanks, consequently the reserve of buoyancy was destroyed; the boat then rapidly gained downward momentum and continued to descend.

* Nautical miles.

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The pointer of the manometer reached its limit of 100 ft. and the boat still descended until she struck the bottom at a depth of 127½ ft. An attempt was made to blow the tanks with compressed air, but what with air-leaks in the service and the external pressure becoming too great, no water could be expelled from the tanks. The whole hull leaked a little, also the torpedo tube let a considerable amount of water into the interior. The hand pumps were resorted to on the failure of the air service, and after twenty minutes' hard pumping the boat lifted and then immediately began to ascend with increasing velocity as the pressure due to the depth of submergence diminished on approach to the surface.

It is generally supposed that the leakage of the kingston valves was due to dirt through want of docking; and had not the boat been under the command of one of the ablest experts in the United States submarine service she might have been less fortunate in reaching the surface without further mishap.

The greatest depth believed to have been reached by a ~~small British~~ Holland boat was when "No. 2" submarine recorded 78 ft.* In this case downward momentum was caused by too much water ballast being taken in. The air service did not fail, ~~as in the "Porpoise,"~~ and the boat, after experiencing a few leaks from rivets weeping, ~~etc.~~, was brought to the surface none the worse for her deep submergence.

The Holland Company, whilst contracting for the U.S. Government, also built an experimental boat called the "Fulton"; she embodies many of the improvements found necessary in the first boats on their trials, and was subsequently sold to Russia for transport to the East.†

In the 1905-6 estimates provision was made for four submarine boats to be built for their navy.‡ They will be of the Holland type, (Plate 109), and of two sizes, one costing 250,000 dols., and the other 200,000 dols. The contract has been awarded to the Electric Boat Company. The length of the two classes will be approximately 105 ft. and 81 ft.

There is a great difference between going "submarine mad" and making steady progress in developing a useful weapon for defensive

---

* "A 4" has since then been down to 90 feet.

† During Russo-Japanese war, 1904-5.

‡ The names of the four boats are to be "Cuttlefish," "Viper," "Tarantula," "Octopus."

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A UNITED STATES HOLLAND MANŒUVRING.

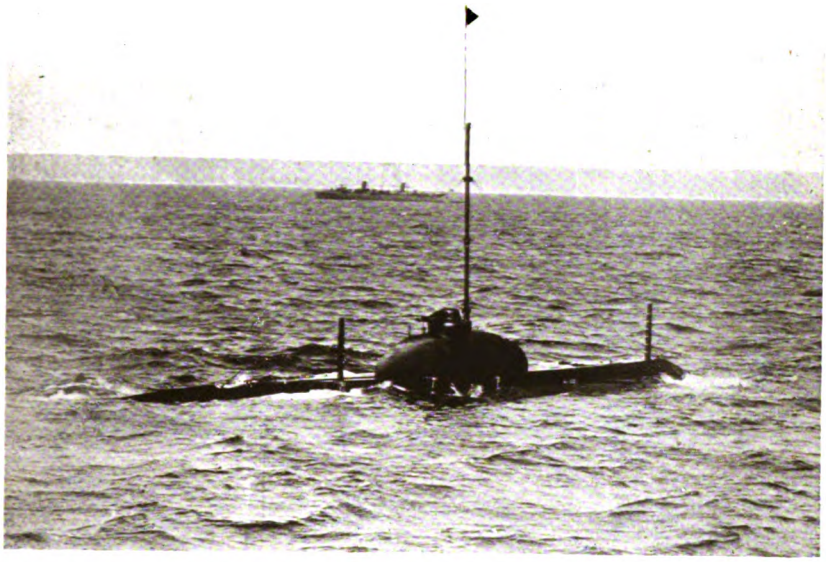

PLATE 37.—*"PREPARING TO DIVE."*
"FLOOD MAIN BALLAST AND AUXILIARY TANKS."

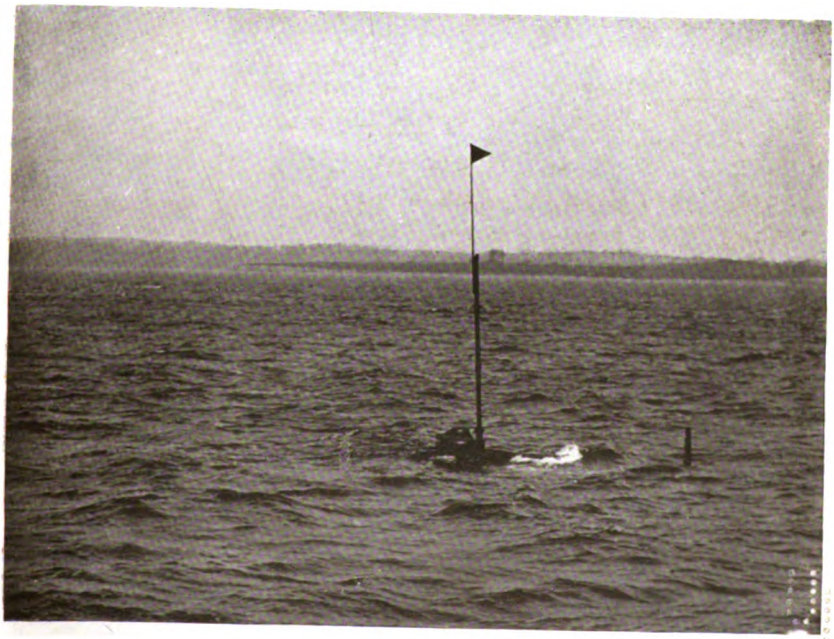

PLATE 38.—*TRIMMED FOR DIVING.*
"CLOSE ALL KINGSTONS AND VENTS."
Reserve of Buoyancy 300 lbs.

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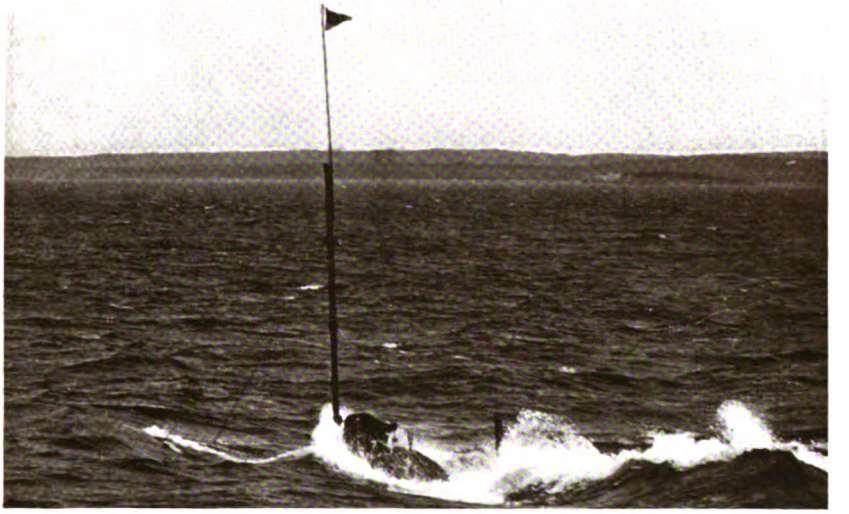

PLATE 39.—"*DIVE.*"

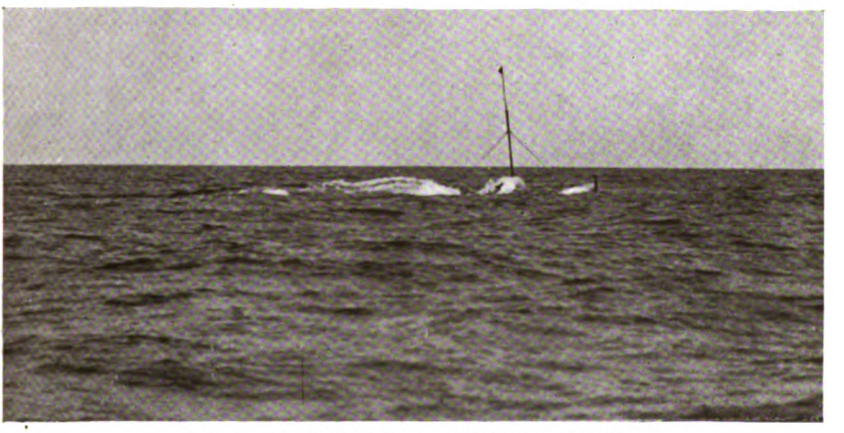

PLATE 40.—*TAKING A SNAP BEARING.*

PLATE 41.—*MIDWAY BETWEEN THE MARK BOATS.*

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purposes. Some United States politicians have been very conspicuous during the last few years in advertising, on every available opportunity, the submarine boat.

This short-sighted policy has been conducted with a total disregard as to the real value of under-water vessels for modern war requirements, and has now defeated its own object, for we notice that the Naval Bureau is at the present time more content to watch the progress other nations are making than to advocate a forward submarine programme. This action is not in keeping with the lessons that are to be learnt from a study of the Spanish-American war, as it may be recalled that, soon after hostilities had commenced, certain United States citizens residing on the Atlantic coast-line, urged by the press, insisted most loudly on protection from Admiral Cervera's fleet, then making across the Atlantic from the Azores. This action prevented the entire American naval forces being used to intercept the enemy's fleet, and afterwards to rigidly enforce the blockade of Cuba.

Such an incident as this in the history of modern nations points to the necessity of having an adequate coast protection irrespective of the sea-going fleets. Submarine evolutions in land-locked harbours, diving displays before visitors at popular seaside resorts, are a most interesting amusement to a large section of the United States taxpayers; but this is not quite what the thinking portion of the population desire, as I am informed by a high U.S. naval authority that they would prefer to see their submarine boats do a little more real work in the open sea. Plates 34 to 41 show an American Holland carrying out endurance trials on the surface and when submerged.

The Lake Submarine Boat.*

Though the design of Mr. Lake was not accepted by the U.S. Naval Bureau, he was not daunted by failure, and in 1894-5 built a small boat of 14 ft. in length and depth 5 ft., with a maximum beam of 4½ ft.

The material used in her construction was yellow pine timber in two layers—the inside layer was lined with felt and outside layer well caulked and then coated with tar. The shape is shown in Plate 42, and resembled a deep chest more than a boat.

Outside the hull are shown two large driving wheels, coupled

* Most of the information and photographs in connection with the Lake boat were kindly furnished by Mr. Whitney of the Lake Submarine Boat Company.

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together by an axle, connected with chain gearing to sprocket wheels inside the boat, these were turned by hand and furnished the motive power for travelling along the bottom when submerged. For air storage the boat carried a soda-water tank with an ordinary plumber's hand pump to act as an air compressor.

To submerge, water ballast was let into tanks until all the buoyancy was destroyed. The boat then sank slowly to the bottom and alighted on the driving wheels. A diving chamber was fitted and allowed a man in diver's dress to leave the boat; this was arranged for by first closing all apertures to make the chamber air-tight; then sufficient compressed air was turned on to make the pressure of air inside equal to the pressure due to the height of water outside; when this balance was established the diving hatch could be withdrawn and allowed the diver to leave or enter the boat at will, the crew inside the boat keeping him supplied with fresh air from a hand pump. The diver, by prearranged signals, could direct the boat over short distances provided the bottom was fairly flat. The diving chamber was opened successfully at a depth of 16 ft.

The boat carried out sufficient demonstrative experiments to allow of Mr. Lake obtaining the necessary capital to start real earnest work in submarine construction of a more ambitious nature. At the Columbia Ironworks, Baltimore, Maryland, the "Argonaut I" was laid down (Plate 43). The hull was built of steel plates $\frac{5}{16}$ in. thick, of circular cross section, with a displacement when submerged of 59 tons, maximum beam amidships 9 ft., and a length of 36 ft. The submergence was done in the same way as the previous boat, anchor weights of 1000 lbs. first being let go, then water ballast taken in until all buoyancy was destroyed.

A similar system of wheels for working when on the bottom was provided; but in this design all the driving mechanism was inside the boat and consisted of a 30-H.P. White and Middleton gasolene engine. This could be geared to the wheels or to the propeller as desired. In the bow an electric searchlight is carried to illuminate the bottom to aid the divers, and the internal electric lighting arrangements were provided to run off the dynamo when being driven by the gasolene engine.

Air compressors and storage reservoirs were also installed; these, with volume of air in boat, would last the crew twenty-four hours at least. A diving compartment was built; this was larger and better

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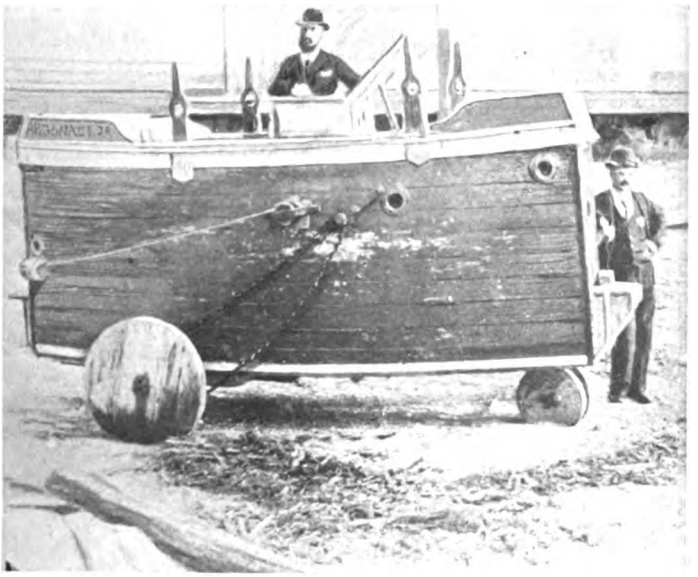

PLATE 42.—*MR. LAKE'S FIRST SUBMARINE.*

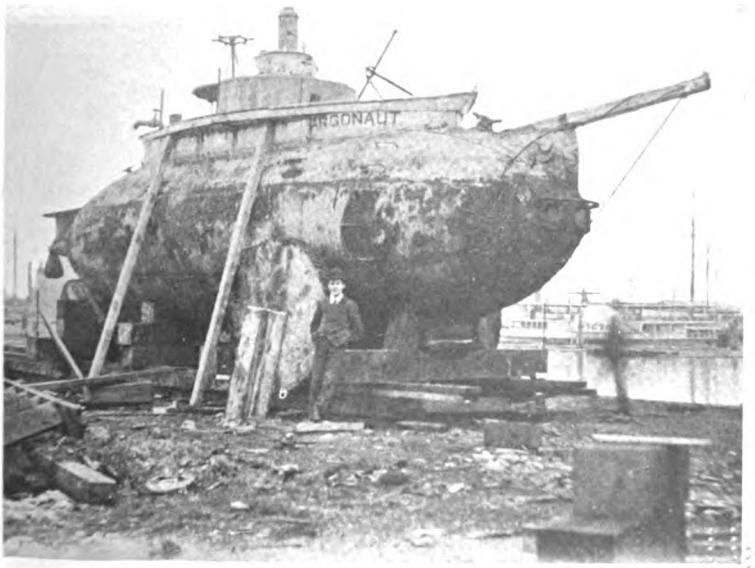

PLATE 43.—*THE "ARGONAUT."*

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equipped than that in the first boat. A float was used on surface with a pipe attached to keep up a constant supply of fresh air when on the bottom. The gasolene engine sucked this down and, if not in use, a blower was fitted to obtain a supply of air; so it was possible to remain submerged for a considerable period.

The crew consisted of five men. They experienced all kinds of rough weather, and in all are supposed to have travelled more than 1000 miles on the surface and on the bottom.

The crew stated that the bottom of the Atlantic is almost as hard and smooth as a macadamised pavement, and in many parts of the American coast there are excellent localities for travelling along on wheels. The distance from the shore suitable for this, in depths less than 150 ft., varies from 15 miles off Cape Hatteras to 75 miles in other localities.

A compass was provided for steering purposes. The tides proved the difficulty, as the pressure on the wheels had to be increased according to strength of tide; this was regulated by the amount of water ballast taken into the tanks, and could be varied from a pound or two to several hundred pounds. The compressed air was stored in two reservoirs made of Mannesmann steel.

The experiments carried out with "Argonaut I" convinced Mr. Lake that the circular ringed hull, while theoretically strong, was not the best form for surface running. In 1899 and beginning of 1900 the "Argonaut I" was reconstructed and then named "Argonaut II." She has been used successfully in salvage work, and exists to-day; is now 66 ft. long, retaining her original size of 9 ft. On the upper part of the hull is built a superstructure which makes her a much more seaworthy craft for surface work, and gets rid of the mass of water at the bow, so noticeable in the Holland boats; this also forms a convenient deck for the crew when working the boat on the surface.

Inside the superstructure are to be found light gasolene tanks built of galvanised steel; these tanks are very carefully caulked and tested to a water pressure of 100 lbs. to the square inch. The capacity of the tanks is 1050 gallons.

All the gasolene tanks are connected to those on the same side of the ship, and these are in connection with a copper service tank, fitted with gauge glass and float, which automatically shuts off the supply; these copper tanks are placed in the engine-room abaft the engines. The gasolene connections are made of seamless brass tubing with brazed joints.

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The stowage of the gasolene tanks exterior to the hull of the boat provides a certain amount of safety, provided the tanks are quite separate from the hull; then no leakage should occur. The tanks in this position are easily kept under observation, and no large quantity of free gasolene should ever get into the interior of the boat, provided ordinary precautions are taken.

Also a six-tube air reservoir built of 8-in. Mannesmann steel tubes tested to a pressure of 4000 per square in., with a capacity of 21 cubic ft., was added. The air stored in this reservoir is never compressed to more than 2000 lbs. per square in., and supplies the air service in connection with the interior of boat, which is, by a special reducer, brought down to 60 lbs.; these air reservoirs are stowed in the superstructure for economy of space. Inside the boat are also four low-pressure air-tanks with a combined capacity of 12½ cubic ft.

The motive power of "Argonaut II" is double that of "Argonaut I"; the driving wheels are now quite separate and merely act as resting wheels, the propeller being the only driving agent. She now carries a 60-H.P. White and Middleton gasolene engine and a 4-H.P. auxiliary dynamo engine, four air compressors, pumps, etc. The crew consists of eight men.

In 1901 Mr. Lake once more approached the Navy department with a proposal to build a submarine for naval purposes, but again he failed to convince the authorities of the value of his craft; however, the officers of the naval department gave encouragement, but not of a substantial nature, and according to their advice he modified the designs of his new boat so as to enable her to compare with the Holland type then under construction for the U.S. Navy.

The modifications suggested by the "Argonaut" in actual trials influenced largely the construction of the "Protector." The new design allowed for greater buoyancy, better sea-going conditions, great fuel capacity, and more accommodation for the crew. The boat was built at Bridgeport, Conn., U.S., and launched on November 1, 1902, having the following general dimensions:—

Length over all	67 ft.	6 in.
Beam, extreme, over guards . . .	14 „	2 „
Depth from top of omniscope with wheels down	24 „	3·8 „
Draught, light cruising condition . .	11 „	9¾ „

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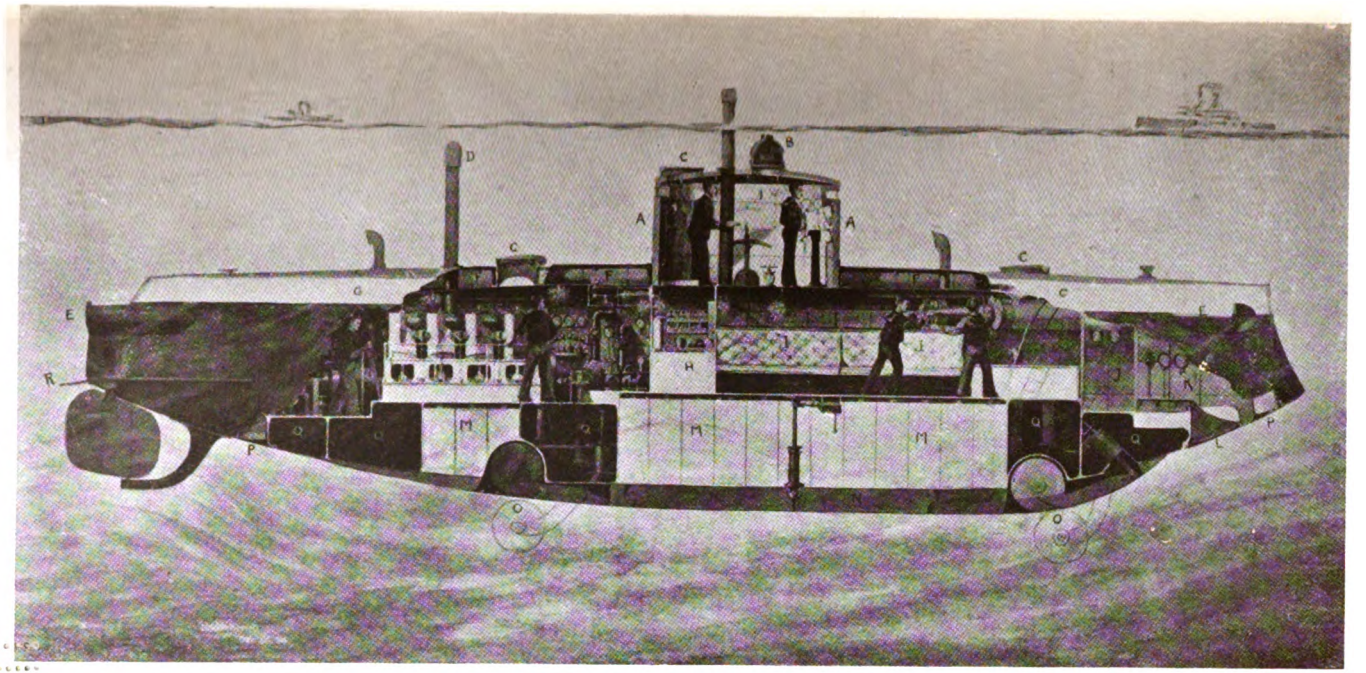

PLATE 44.—*INBOARD PROFILE OF "PROTECTOR."*

A, A.—Bronze Conning Tower.
B.—Sighting Hood.
C, C.—Hatches.
D.—Exhaust from Engines.
E, E.—Torpedo Tubes.
F, F.—Gasolene Tanks.
G, G.—Line of Spindle Hull.
H.—Galley Compartment.
I, I.—Crew Space.
J.—Air Lock.
K.—Diving Compartment.
L.—Diving Door.
M, M.—Storage Batteries.
N, N.—Drop Keel.
O, O.—Wheels.
P, P.—Anchor Weights.
Q, Q.—Ballast Tanks.
R.—Horizontal Rudder.

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Displacement, light	136·3 tons
„ awash	157·1 „
„ submerged . . .	174·35 „
Area, midship section, cruising trim .	102·32 sq. ft.
„ „ „ submerged . .	147·2 „ „
Height of C.G. above base of keel . .	83 in.
„ C.V. „ „ „ . .	98 „
C.G. below C.V., cruising trim . .	15 „
„ „ „ deck awash . . .	9 „
„ „ „ submerged . . .	7·3 „
Height of C.G. above base of keel, superstructure full, ballast-tanks empty .	93 „
Height of C.G. above base of keel, superstructure and conning-tower, full, ballast-tanks empty . . .	96 „
C.V. aft of forward vertical . . .	371·4 „
C.G. aft of forward vertical, cruising trim	374 „
C.V., cruising trim	3.16 „
Tons per inch immersion at cruising trim	1·3

The actual hull is spindle-shaped, 65 ft. long, with a maximum diameter of 11 ft. 2 in. Over this goes a light superstructure. The hull and conning-tower have been constructed to stand a pressure of 150 ft. The main frames are spaced 20 in. apart and are thirty-six in number. The midship portion of the boat for nearly ten frames is quite cylindrical (Plate 44). The hatches are three in number, two elliptical and one circular, and closed with sliding dogs worked by hand wheels and screws. The bow and stern castings are made of malleable iron and conical in shape. The tank bulkheads are worked as high as the floor plates and are tested to 50 lbs. to the square inch.

The "Protector" has three torpedo tubes, two placed forward and one in stern, and arrangements have been made for her to carry 18-in. Mark III Whiteheads, three stowed in the tubes with two spare.

A low-pressure reservoir is used off the 60 lbs. air service for firing torpedoes. The tubes are usually loaded by floating the torpedoes into them—a matter of considerable difficulty—or by opening up the engine-room hatch and sending the torpedo down in two portions parted at the engine-room and ballast-chamber joint. A compartment is arranged forward for a diving chamber, as in the "Argonaut,"

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and consists of an air lock 42 in. long built into a bulkhead at frame No. 6, and fitted with water and air-tight doors, the whole being capable of standing a pressure of 75 lbs. per square inch.

This chamber is fitted with a connection to the low-pressure air system, a gauge with two hands, one of which registers the pressure due to depth of water and the other the air pressure within the compartment, and a telephone; also in the bottom of the compartment, forming a part of the hull, is a cast-iron door, hinged at its after end and stiffened with transverse ribs which, when the door is open, serve as steps, this is raised by small hand winches with wire-rope falls, and secured with dogs. Around the door is a coaming extended 30 in. above the hinge door.

To open the diving door when on the bottom, the air-lock doors being closed, a valve on the air connection is opened and the pressure in the compartment allowed to increase gradually until the two hands on the gauge balance. A try-cock in the door is then opened and the balance of the pressure verified. The door is undogged and allowed to swing open, giving, in clear water, a good view of the bottom.

A diving suit, fitted with a telephone receiver in the helmet, is provided, the air hose being connected with a low-pressure air tank in the compartment, the pressure being controlled by the diver through a valve in his helmet; thus persons in the diving compartment are in telephonic communication with the diver and with the rest of the boat.

The inventor claims that the diving compartment provides for:—

1. Cable cutting.
2. Destruction of mines.
3. A means of escape for the crew in case of total disablement of the boat.
4. A means of communication with shore by cable when on outlying patrol duty.

In demonstration of these features the diving door has been opened in depths up to 32 ft. A member of the crew in diving suit and one in bathing suit has been sent out, the latter to demonstrate the method of escape. A distinctive feature of this boat is the drop or false keel, arranged as follows:—

Two sheets of steel $\frac{3}{4}$ in. thick secured to the lower part of the centre of the hull and separated about 18 in. from each other form

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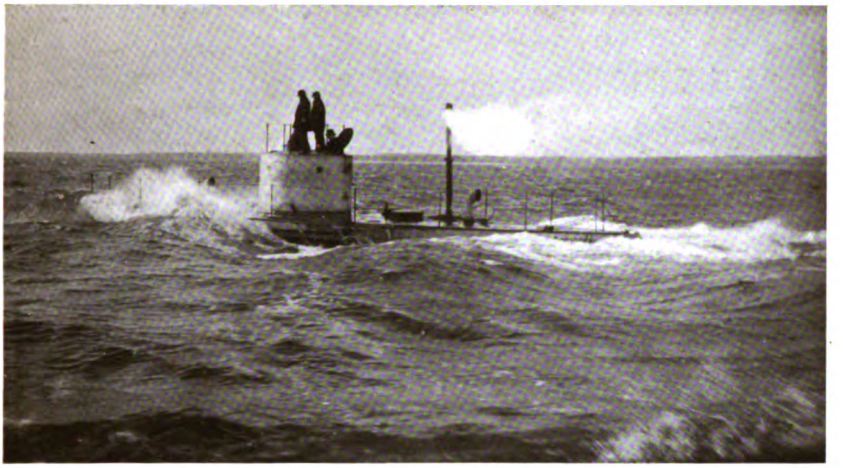

PLATE 45.—*RUNNING AT "FULL SPEED" ON SURFACE (Broadside View).*

PLATE 46.—*RUNNING AT "FULL SPEED" ON SURFACE (Bow View).*

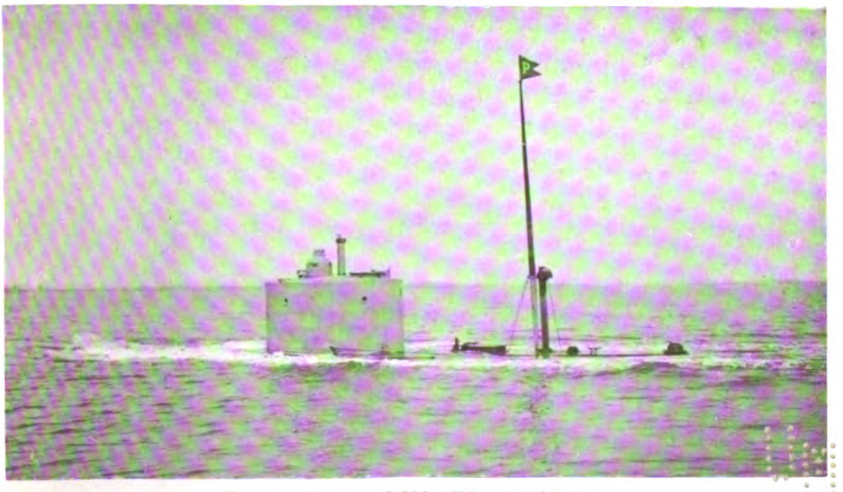

PLATE 47.—*"TRIMMED AWASH."*

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the keel. These plates are 18 in. high in their central part, gradually diminishing toward their extremities, which terminate in a point; between these two plates is located the false keel, which consists of two pieces of cast iron 7 ft. long by 17 in. square, with a combined weight of 10,000 lbs., held in position by a shaft on which is shipped a wrench; when the boat is submerged, the fastening of the two portions of the drop-keel is such that a quarter turn of the wrench will release the entire weight, 10,000 lbs., in an emergency.

The ends of these pieces have a shoulder corresponding to the support upon which they rest on the true keel. The object of this arrangement is to facilitate their fall. Inside the false keel are located two wheels, by which the submarine boat can travel upon the bottom when being driven by its screws. Within the hull, and also within the space surrounded by the two sheets of the keel, are two cavities in which the wheels are housed when the vessel is cruising. The supports of the wheels are bifurcated and turn upon a shaft secured to the cheeks of the keel, and the extremities of these arms are connected to hydraulic cylinders, which in turn are cushioned by pneumatic cylinders. The object of the hydraulic cylinders is to raise or lower the wheels and operate by means of a hand pump; the pneumatic cylinders serve as springs to deaden the blow that might be produced upon the wheels as they travel upon the bottom, and also the blows which may be produced when the vessel rests upon the bottom during a storm.

Lieutenant Halligan says that during the trials of "Argonaut I," while it rested upon the bottom near Cape Henry, at a depth of 30 ft., the agitation of the sea was such that the vessel rose and fell some 10 in., which without the above arrangement would have been disastrous to the machinery. As the effects of these blows were irresistible, there has been added to the "Protector," and to the new submarines in process of construction, a second cylinder, which serves as a cushion, and which overcomes this difficulty.

Both the wheels and the fork in which they rest are very strong, the former having a diameter of 24 in. and being 10 in. wide, and the wheel and its support together weigh approximately 2000 kilos.

When the wheels are down they maintain their position by force of their own weight, and exercise no appreciable influence upon the hydraulic cylinders. In order to navigate under these conditions the vessel is given a little negative buoyancy, scarcely sufficient for her to

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rest upon the bottom, the captain being able to regulate this to within a few kilos, according to the ground over which he is moving. In view of this fact the work thrown upon the wheels is insignificant; they scarcely rest upon the bottom, and their weight is sufficient to maintain them in position.

That part of the keel between the two vertical plates that is occupied neither by the wheels nor the false keel is filled with timber fixed in place by means of bolts.

The anchors consist of two 500-lb. mushroom-shaped weights, one each end, to which is attached 250 ft. $\frac{5}{8}$-in. steel wire worked by electric winches controlled by switches in conning-tower. To submerge the boat statically water ballast is taken in until the buoyancy is a little less than the two 500-lb. weights when on the bottom, the electric winches are then hove round and the bottom can be kept in spite of tide at the depth required. There are two 2-H.P. Dialil motors supplied with electrical energy at a pressure of 110 volts from accumulators and controlled by switches in the conning-tower.

Mr. Lake has introduced a very much larger conning-tower than usually seen in submarine boats. To those who have worked in cramped conning-towers this design will appeal chiefly for enabling the captain of the boat to obtain far better relative vision than if flattened with his nose against a glass scuttle, as in the "Holland" type, and allows of better judgment of distance when running with conning-tower battened down. Plates 45 to 50 show the "Protector" under working conditions.

This increase in size of conning-tower is provided for the following purposes:—

1. To provide a buoyancy moment well above the centre of gravity, thus contributing to stability.

2. To localise the control when submerged.

3. To facilitate the surface navigation of the boat in comparatively rough seas.

4. To provide a compass position, well removed from the magnetic influence of the hull, electric wires, etc.

The details of the conning-tower are: height 10 ft. 1 in., 4 ft. 7 in. wide, elliptical in shape, extending 6 ft. 5 in. above the spindle hull, and is situated between frames No. 14½ and No. 20½. For a height of 33 in. the structure is of steel plate, the remainder being of tobin bronze.

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PLATE 48.—"*TRIMMED FOR DIVING.*"
Reserve of buoyancy about 2 240 lbs.
Two of crew showing safety of their boat when in this trim.

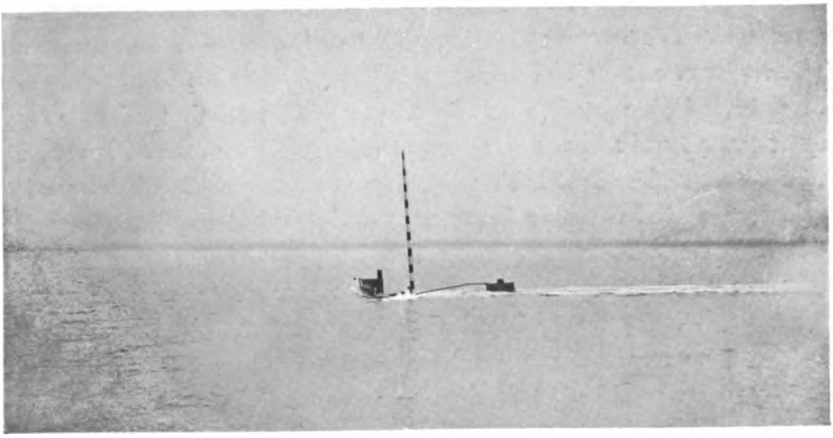

PLATE 49.—"*DIVE.*"

PLATE 50.—"*RUNNING SUBMERGED.*"

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The conning-tower carries a sighting hood, omniscope,* hatch, suitable lenses for affording an all-round view of the horizon, and in the interior is most of the controlling mechanism of the boat, namely :

Steering wheel for vertical rudder.

Operating wheel for controlling the system of four hydro-planes; each is fixed on its own shaft and works in union with those on the opposite side.

Diving wheel for controlling horizontal rudder.

Engine and motor telegraphs.

Telegraph controlling engines, motors and pumps.

Controlling gear of electric anchor hoists.

Valves for filling superstructure.

Air vents and air connections controlling filling and blowing out of superstructure and ballast tanks.

Gauges and dials as follows :

One 15-in. depth gauge registering to 75 ft.

„ 6 „ „ „ 150 „

Dial showing inclination of hydro-planes.

Dial showing inclination of horizontal rudder.

Clinometer showing longitudinal trim.

Buoyancy indicator.

Water column showing level of water in superstructure.

When in cruising condition a detachable steering wheel and engine telegraphs are shipped on top of the conning-tower. In the dome of the conning-tower, forward of the sighting hood, is worked a bronze compass case, carrying a Ritchie compass with a 7-in. double card, visible from above and below, and situated 3 ft. 2 in. above the steel portion of the tower.

An air-compressor is fitted abaft the port engine geared off main shaft, which reduces speed 2 to 1 and can be run by gasolene or motor, and compresses up to 2100 lbs. a volume of 60 cubic ft. in one hour, and the reservoirs are placed in the superstructure as in the former boats.

The storage batteries † are of the Gould type with an output of 100 E.H.P. for three hours. They furnish the power for working two propellers, one motor to each shaft; to these can also be coupled one

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* See Chapter XIX, on Periscopes.

† See Storage Batteries, Chapter XVIII.

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four-cylinder gasolene engine of the four-cycle type, giving 120 H.P. to each shaft. The combined horse-power of gasolene engines and motors is 350.

Three methods of ignition are provided, namely, primary batteries, magneto and direct current taken from the storage batteries.

Two 4-in. suction pumps are worked off main shafts by mechanical gearing and can be rotated by motor or gasolene engine; three small auxiliary pumps complete the outfit:

Speed	.	10 knots.
Awash	.	9 „
Submerged		6–7 „

Very successful trials were carried out with this submarine, and the United States War department received the report of the Board of Officers appointed to witness and report upon the "Protector," commonly known as the "Lake" submarine boat. The conclusions and recommendations were as follows:—

"The Board believed that this type of submarine boat is a most valuable auxiliary to the fixed mine defence, and in cases where channels cannot be mined owing to depth, rough water, swift tides, or width of channel, it will give the nearest approach to absolute protection now known to the Board. The boat can lie for an indefinite time adjacent to the point to be defended, in either cruising, awash, or submerged condition, by its anchors or at the bottom, ready for instant use, and practically independent of the state of the water, and in telephonic connection with the shore, or can patrol a mined or un-mined channel, invisible to the enemy, and able to discharge its torpedoes at all times. It possesses the power of utilising its engines in every condition except the totally submerged, and can always charge the storage batteries when on the surface, necessitating its return to shore only when gasolene must be replenished. In narrow channels the boat or boats would have a fixed position with a telephone cable buoyed or anchored at the bottom. In wide channels they would patrol or lie in mid-channel or where they could readily reach approaching vessels.

"As a picquet or scout boat outside the mine-field, or even at extreme range of gun-fire, telephone communication can be sustained and information received and instructions sent for attacking approaching vessels.

"The test at Newport demonstrated the ease with which the boat can locate and pick up cables, and with minor alterations in the

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present model, junction boxes, etc., can be taken into the diving compartment and repaired at leisure, while absolutely protected from hostile interference. The faculty possessed by the boat of manœuvring on the bottom and sending out divers leaves little or nothing to be desired in its facilities for doing this work.

"For the attack, the boat shows great superiority over any existing means of attacking mine-fields known to the Board.

"It can run by any mine-field, as at present installed, with but little or no danger from the explosion of any particular mine or from gun-fire during the few seconds it exposes the sighting hood for observations, and can attack at its pleasure vessels in the harbour.

"The Board personally witnessed the ease with which cables can be grappled, raised, and cut while the boat is manœuvring on the bottom; mine cables can be swept for, found and cut, or a diver can be sent out for that purpose.

"The Board recommends consideration of the foregoing by the General Staff. The question of the use of the Whitehead torpedo as part of the fixed mine defences, fired from tubes on shore, is now receiving consideration. Where channels are wide and water swift this use of the Whitehead will be very limited. With boats of this type the Whitehead can, it is believed, be carried within certain effective range in all ordinary channels, and this alone will warrant the consideration asked for. The Board recommends, in consequence of its conclusions, that five of these boats be purchased for use in submarine defence.

"These submarines to be used for protection of:

Eastern entrance of Long Island Sound.
Entrance to Chesapeake Bay.
San Francisco harbour.
Puget Sound; and one for instructional purposes for school of submarine defence."

This boat during 1904 was sold to Russia, and the Lake Company secured a valuable contract for four submarines for that country.* These boats were built at the yards of the Newport News Shipbuilding and Dry Dock Company, Newport News, Va., at the same time the "Simon Lake X" was constructed. The new boats were all improvements on their prototype the "Protector." In outward appearance they are much alike, but in many essentials a great advance has been

* See Chapter XIII.

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made, particularly with propellers, which are made of bronze, carrying three blades 5 ft. in diameter at a 5-ft. angle, in place of the old style with a diameter of 45 in. and a 3-ft. angle. The new boats are 70 ft. long with a maximum beam of just over 11 ft. Outside the hull, as in previous designs, a light steel ship-shaped structure is built within which is stored the gasolene tanks and manganese bronze flasks that are charged with compressed air. The main hull is stronger than that of the first boat and capable of withstanding a pressure at a depth of 200 ft.; the large conning-tower peculiar to the Lake type is maintained and allows the commanding officer to enjoy a centralisation of control and direction of unusual scope. The gasolene engines—one engine on each propeller shaft—will drive the boat at a speed of 10 knots; these are the White and Middleton type (see Plate 76).

For complete submerged propulsion a motor on each shaft, drawing energy from storage batteries, is provided; these batteries are of sufficient capacity to last for four or five hours' continuous work.

For spurts on the surface the gasolene engines and motors can combine in driving the boat; with the latest design of propeller it is estimated between 9 and 10 knots can be obtained when running submerged. The "Simon Lake X" can keep a very even depth-line by her four hydro-planes, located two on each side amidships; these pivotal planes will force the boat below the surface when under way, and, because of their symmetrical disposition, they ensure the boat rising and submerging on a fairly even keel. To run on the bottom the vessel will travel on two big steel wheels arranged tandem in the keel-line, propulsion being by the propellers.

In discussing this feature of the Lake boat with an officer who actually did a trial trip in one of the latest type, he mentioned that the boat was made to travel along the bottom and entered a deep hollow; the manometer showed the increasing depth; the boat travelled with wonderful precision, and was under perfect control, coming out of the hollow with no appreciable effort, the actual contact being scarcely felt on reaching the bottom, due to the cushioning arrangements.

When running under water during this trial two of the crew were moved from right forward to right aft without affecting the longitudinal stability to any extent. Also the bottom could be examined from the air-lock for miles.

The many methods of coming to the surface in this type of boat are:

1. The submergence is always made with a reserve of buoyancy of some 300 lbs.

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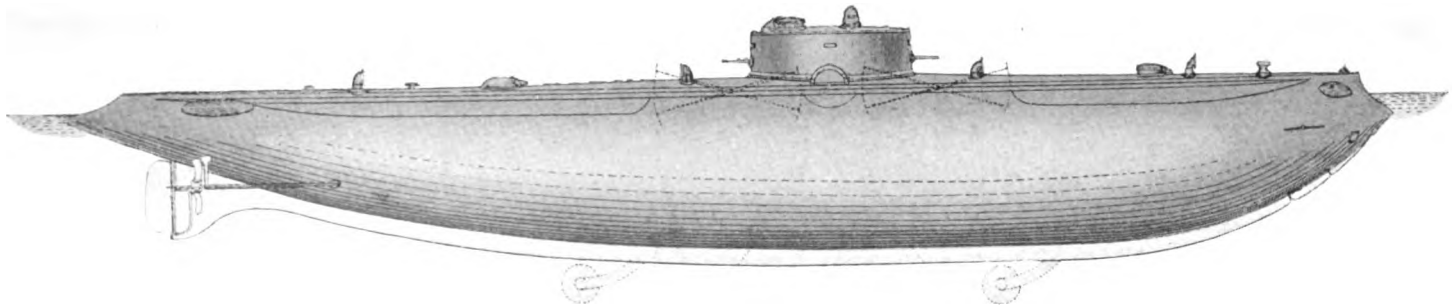

FIG. 26A.—*THE LATEST SUBMERSIBLE. LAKE TYPE.*

The principal features are:—Great Longitudinal Stability, Large Surface Reserve of Buoyancy, 4 Torpedo Tubes, 8 Torpedoes, Diving Compartment, Hydro-planes, Safety Weight, 2 Rapid Fire Guns for Surface Protection. Submerged Speed, 7 knots; Surface Speed, 14 knots.

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2. Ejecting water ballast by air-pressure, electric pump or hand pump.

3. Release of anchor-weights of ½ ton each.

4. Release of a 5-ton drop-keel.

5. The crew can escape through the diving compartment.

These safety devices are significant when we recall the submarine accidents of the last few years.

Mr. Lake has undoubtedly devised a system of even keel submergence which is preferable to the porpoise-like dive of the Holland type. His arrangements also ensure a fair amount of longitudinal stability, and no seaman will doubt the ability of this class of boat when running on the surface to stand a considerable sea-way. In a rough sea there may be some difficulty in trimming the boat for diving, but this is inherent in all types. When once submerged, there is no difficulty in maintaining a uniform depth-line at any speed within the capabilities of the propelling motors.

In 1905 the United States Government passed the following law:

"The Secretary of the Navy is hereby authorised in his discretion to contract for or purchase sub-surface or submarine torpedo-boats in the aggregate of, but not exceeding, eight hundred and fifty thousand dollars; provided that, prior to said purchase or contract for said boats, any American inventor or owner of a sub-surface or submarine torpedo-boat may give reasonable notice and have his, her, or its sub-surface or submarine boat tested by comparison or competition, or both, with a Government sub-surface or submarine torpedo-boat, or any private competitor, provided there be any such, and thereupon the Board appointed for conducting such tests shall report the result of said competition or comparison, together with its recommendations, to the Secretary of the Navy, who may purchase or contract for sub-surface or submarine torpedo-boats in a manner that will best advance the interests of the United States in torpedo or submarine warfare; and provided further, that before any sub-surface or submarine torpedo-boat be purchased or tendered for, it shall be accepted by the Navy department as fulfilling all reasonable requirements for submarine warfare, and shall have been fully tested to the satisfaction of the Secretary of the Navy. To carry out the purpose aforesaid the sum of eight hundred and fifty thousand dollars is hereby appropriated, out of any money in the Treasury not otherwise appropriated; and to make up the sum of eight hundred and fifty thousand dollars, the sum of five hundred thousand dollars carried, or

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such part thereof as may remain unexpended, and authorised in the Naval Appropriation Act, approved March third, nineteen hundred and three, is hereby re-appropriated."

The Lake Company requested a trial of its "Simon Lake X" in competition with a Government Holland under the hardest conditions of sea and weather that could be obtained.

For some unexplained reason the Navy department did not see their way to grant this request for competition, and the Lake Company appealed to Congress, but with little success. It may be recalled that the Army Board reported favourably on the "Lake" boat, but the Bill, which subsequently passed the United States Senate, authorising the construction of a boat of the "Lake" type was finally killed in the House of Representatives. The position now* is that this enterprising company have, after constructing several boats for foreign Governments, at last forced the United States authorities to undertake comparative tests in Narragansett Bay before a special Naval Board, to decide what type of submarine is to be purchased for the American Navy in 1907–8.

The "Octopus," of the "Holland" type, is to be pitted against one of Mr. Lake's even-keel boats. There will be three speed tests over a course of a mile—first in cruiser condition, second awash, and third submerged. Both the speed and the manipulation tests will be made under gasolene and electric power.

The severest test is the submergence for twenty-four hours in order to determine the habitability of the craft. The "Octopus," with a radius of action of 1000 miles, has made 9 knots submerged. She is 100 feet long and of 255 tons under-water displacement, and has a crew of fifteen. The "Lake" is 85 ft. long and of 220 tons submerged displacement, with a speed of 8 knots submerged.

After scrutinising all the information available, I am certain that several features of the "Lake" design will be embodied by most nations in the construction of future boats, the chief of which perhaps are "the even-keel method of submergence" in preference to the "dynamical dive" of the Holland boats, also the provision of a safety keel and diving compartment; this latter forms a ready means of communicating with the surface should the boat through some small mishap find herself on the bottom and unable to rise.

* May 1907.

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CHAPTER XII.

BRITISH SUBMARINES.

The late Viscount Goschen stated on April 6, 1900, in the House of Commons: "Close attention has been given by the Admiralty to the subject of submarine boats. The submarine boat, even if the practical difficulties attending its use can be overcome, would seem, so far as the immediate future is concerned, to be eventually a weapon for maritime Powers on the defensive, and it is natural that those nations which anticipate holding that position should endeavour to develop it. The question of the best way of meeting its attack is receiving much consideration, and it is in this direction that practical suggestions should be valuable. It seems certain that the reply to this weapon must be looked for in other directions than in building submarine boats ourselves, for it is clear that one submarine boat cannot fight another."

In the same year Mr. Arnold-Forster also said: "The Admiralty are not prepared to take any steps in regard to submarines, because this vessel is only the weapon of the weaker nation. If, however, this vessel can be rendered practical, the nation which possesses it will cease to be weak, and will become really powerful. More than any other nation, we should have to fear the attacks of submarines."

At a later date we notice Sir William White contributing a series of most interesting articles on this subject to the *Times*, from one of which the following extract is taken. "It may be worth stating, although the fact should be obvious, and the statement involves no breach of official confidence, that everything done in France and the United States from 1895 onwards in connection with submarine construction was thoroughly well known and carefully considered by the Admiralty at the time. There was no difficulty in undertaking here the design or construction of submarines had it been considered desirable to do so; and the work of building could have been done with greater rapidity; but it was decided to await

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developments elsewhere before making a start. Writers in the popular press of this country, seeking for 'some new thing' to illustrate the short-sightedness and extreme conservatism of British naval authorities, waxed eloquent in condemnation of the Admiralty for long delay in taking similar action. Underlying most of these criticisms was the assumption—which was itself a fallacy—that, if foreign navies adopted submarines, it followed that the Royal Navy must possess an equal or greater force of such vessels, their numbers being governed by the numbers of foreign vessels of similar type. In other words, it was tacitly assumed that submarines must constitute the best and necessary reply to foreign submarines." *

Naturally the late Chief Constructor of the Navy defends a comatose policy which was partly in accordance with his advice.

If foreign nations develop a submarine-boat defence for the protection of their principal ports and coast-line, it seems clear their battle squadrons and raiding cruisers are freer to operate in whatever way the trend of strategic opinion shows advisable. It is an accepted naval axiom that a navy is used to the best advantage when acting on the offensive. It cannot be utilised to this full advantage unless the coast defence is fairly secure and so recognised by the whole country; once the submarine boat is developed into a practical fighting unit it is as valuable to us as to any other nation; an efficient submarine-boat defence of our shores, supplemented by torpedo-boats and destroyers, will leave our fleets free to act on any desired objective. Nobody can say we have too many ships for this work; therefore the consideration of a suitable coast defence is of the greatest importance to us. A brief reference may, in connection with this question, be made to the raids of the Vladivostock squadron,† off the coast of Yezo, when several Japanese merchant coasting-ships and transports were sunk either by gun-fire or the torpedo. Any country with a large sea frontier may expect attacks of this description during the whole period of hostilities. However powerful it may be as a superior maritime belligerent, it is practically impossible to guard against raiding cruisers in every locality.

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* Taken from Sir William White's articles on Submarines, Literary Supplement of *Times*, March 1905.

† April 1904.

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Also the proximity to our coast-line of possible enemies who at any time might obtain a local temporary command of the sea must be remembered. We are certain to have raids on our shipping in the vicinity of big mercantile marine centres, therefore any means by which disorganisation of trade can be avoided in these quarters must be of the greatest value. The submarine boat offers at the present time the best-known system of mobile coast defence. If this vessel is developed for defensive purposes, it may be stated that any venture to transport troops across the narrow waters in the vicinity of our southern and eastern coast-line would be a hazardous undertaking, and once more the invasion bogey is checkmated. This country has been exceedingly backward in the development of the submarine boat; the adherents of this half-hearted policy argue that any maritime Power can provide, by means of this weapon, a very efficient coast defence at comparatively small cost, without having to go to the expense of building enormous battleships at prohibitive prices; they also contend that every advance made in our designs benefits other nations, as it is impossible to keep the broad lines of progress confidential.

These statements are perfectly true. But can we as an Imperial Power afford to accept the handicap of our neighbours being more efficiently armed with a distinct type of weapon than ourselves?

The conservative spirit of many successive Boards of Admiralty religiously followed the line of policy first advocated by Earl St. Vincent in regard to the experiments made by Fulton with under-water boats, inasmuch as any provision for research in the problems appertaining to sub-aqueous navigation was shirked in estimate after estimate.

Fortunately our few politicians interested in naval progress were strongly of the opinion that we could not afford to postpone this question much longer, and consequently forced the attention of the authorities to the progress France was making in the development of submarine boats. This nation has shown a truer foreknowledge of the potentialities of these craft than any of the other maritime Powers; her successes in the last few years cannot fail to concentrate the attention of thinking people in all countries on the practicability of these latest instruments of naval warfare.

The necessity for constructing these weapons has then been forced

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upon us by those nations who are attaching great importance to this type of torpedo vessel, and who are developing their most essential qualities, that of defence and limited offence. At last experiments in this direction were reluctantly undertaken, but not until the hulls of the first boats were well framed up did the Admiralty indicate their policy thus. In the explanatory statement of the First Lord of the Admiralty of the naval estimates for 1901–2 the following passage occurs.

"Five submarine vessels of the type invented by Mr. Holland have been ordered, the first of which should be delivered next autumn. What the future value of these boats may be in naval warfare can only be a matter of conjecture. The experiments with these boats will assist the Admiralty in assessing their true value. The question of their employment must be studied and all developments in their mechanism carefully watched by this country."

These boats are somewhat similar to the six Hollands ordered by the U.S. Government in 1900.

We find, a few days later, Mr. Arnold-Forster in the House of Commons (March 18, 1901) remarking: "I will not say much about submarine vessels, but I will say that I am glad that the Admiralty, under the advice of Lord Goschen, took the view that it was wise not to be found unprepared in regard to this matter. We have a great amount of information about these boats, but we do not attach an exaggerated value to it. But we believe that an ounce of practice is worth a ton of theory, and that when we get officers and men to see these boats, they will learn more from them than from many reports which come from foreign countries. One thing stands between the submarine boat and efficiency, and that is the motor by which it is propelled; but there is no disguising the fact that if you can add speed to the qualities of the submarine boat, it might in certain circumstances become a very formidable vessel."

Some interesting facts that came out during the sitting of the Committee on Naval Affairs of the United States House of Representatives in connection with the introduction of the Holland submarines into this country are worth repetition.

This Committee had been making a thorough and exhaustive enquiry into the question of submarine boats and were examining numerous witnesses. Amongst these was Mr. Isaac L. Rice, president

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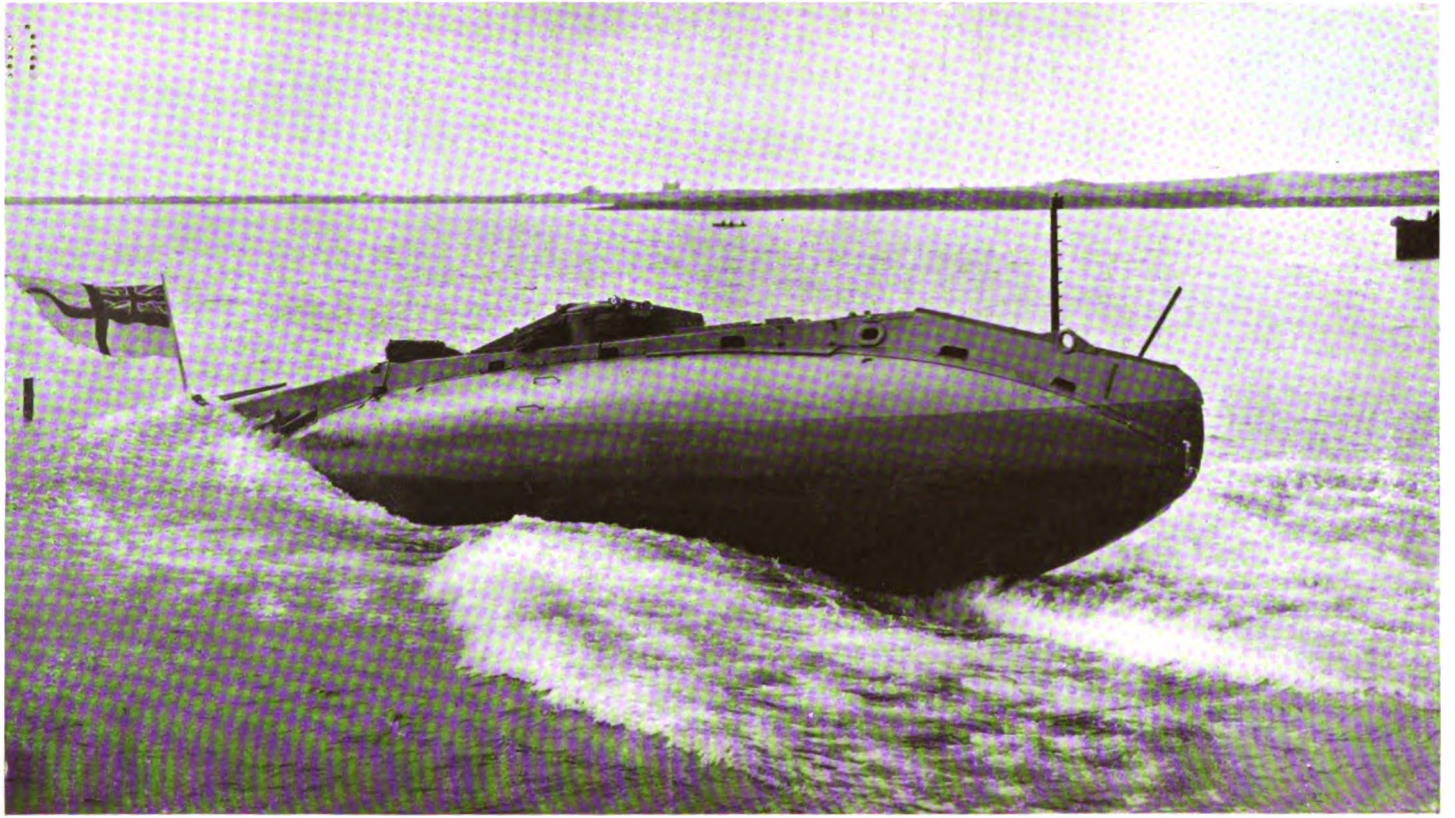

PLATE 51.—*LAUNCH OF "No. 1" BRITISH HOLLAND SUBMARINE.*

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of the American Holland Boat Company, who, in the course of his evidence, stated "that the British Government paid £35,000 for each of the five 'Holland' boats provided for in the Navy estimates of 1901–1902, and that the price paid for exactly similar craft by the United States Government was 170,000 dollars (about £34,000)." Mr. Rice continued: "I went to Europe and made negotiations with the British Government for the sale of five of our submarine boats, and they gave the order without having seen our boat, or knowing anything about it except by description. After I made that arrangement I had to look round for some British builder to build the boats. I asked the British Government whether they would permit me to turn my contract with them over to a shipbuilding firm, and have the boats built in England instead of our going to the expense of building them here and taking all the risks of transportation across the water. They agreed to that, and I went to Vickers, Sons and Maxim and made a suitable arrangement with them based on a sharing of profits." *

The Admiralty thus acquired the mass of information collected by Mr. Holland in his many years of experimental work. Also, according to Sir William White, a guarantee was given by the Holland Boat Company that any further improvements made in the United States during the continuance of the agreement should be placed at the Admiralty's disposal through Messrs. Vickers.†

The first boat was laid down in this firm's shipyard at Barrow-in-Furness and was launched on November 2, 1901, under the name of "No. 1" (Plate 51).

The Admiralty were not prepared to accept the boat from the Holland Company unless it had been ascertained that she could dive, therefore the Company sent over an expert crew to this country to carry out the first trials, under the direction of Captain Cable, their able engineer, who had superintended the building of the boats in America; the initial experiments were carried out in the Devonshire and Buccleuch Docks at Barrow, then afterwards in the Irish Sea.

In giving evidence before the Committee on U.S. Naval Affairs, Captain Cable said that in the first British boat, known as

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* *Westminster Gazette*, July 23, 1902.

† Sir William White, *Times*, March 1, 1905.

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"No. 1," * he made about twenty-five to thirty dives in the Irish Sea. "It is always rough there; but the boat was very successful. We had no trouble with it in any way. We instructed the naval crew for the Admiralty to take charge of the boats while we were there—a captain and four lieutenants in the service—and these officers were even more enthusiastic than our own officers in the expression of their opinions respecting the performances of the newest type of 'Holland' craft. These officers made reports to the British Admiralty, but they were not made public. The Admiralty accepted the first boat."

With regard to the Government requirements in England, Captain Cable further remarked, "Their special requirements are less than ours. They do not require the speed that the United States Government does, and they are not as accurate about the firing of the torpedo. All the British Government wanted was to see the boat under water, to see that she could dive and manœuvre, and that she was capable of being properly handled under water. They do not care anything about whether we fire torpedoes or not. In fact, in the first boat that was accepted we did not fire any torpedoes at all. They have had enough torpedo practice to know all about the torpedo. It is only the boat they want to see. They know that if the boat has a tube in her she will fire the torpedo."

These first submerged trials were started in February 1902, and deep-sea trials followed in April of the same year. Captain Cable's remarks were very much to the point; all the Admiralty wanted was a diving boat to be utilised as a basis for experiments of an extended nature.

After the first boat was built several improvements were made, all of which were embodied in the construction of the other boats.

The building up of a large number of submarines during the last few years has proceeded with methodical regularity. A continuity of ideas has been noticeable in all these designs.† Many ingenious devices and contrivances have been introduced on the recommenda-

* Captain Cable handed "No. 1" submarine over to Captain Bacon, R.N., D.S.O., a distinguished torpedoist, who was selected by the Admiralty for the important duty of experimenting and introducing this new weapon into the British Navy.

† Captain Bacon superintended all the early designs on behalf of the Admiralty, and was succeeded in this work by Captain Edgar Lees, a well-known torpedo officer.

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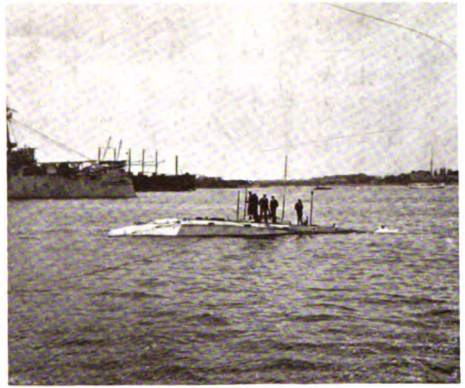

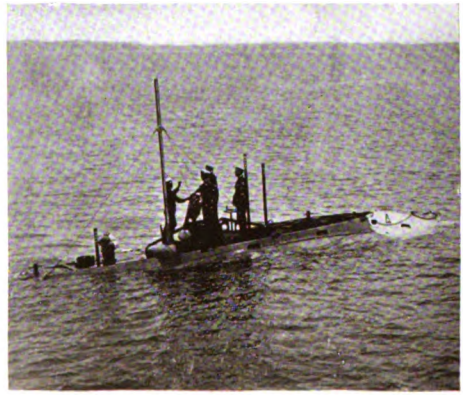

PLATE 52.—*FOUR VIEWS OF "Nos. 3 and 4" SUBMARINES EXERCISING ON SURFACE.*

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tions of the various captains of the boats, based on actual experience of requirements. This progressive system has made each boat in many respects better than her previous sister. Plate 52 shows "Nos. 3 and 4" Hollands manœuvring.

Captain Cable stated that the Irish Sea was always rough, and he was not far wrong. The first experiments were carried out in sometimes the severest of winter weather, the boats having at times to plough their way through sheet ice on their passage down the docks for surface trials in the open sea. The whole of the first five submarines eventually passed through their duration tests with highly satisfying results. Small troubles in the early stages were experienced with the electric accumulators, but these difficulties were soon surmounted.

It is unnecessary to go through any details of these boats, except to give their dimensions, which are in the main features similar to all the Hollands. The following extract from the specifications of Holland "No. 10" ~~are not confidential~~, and will serve the purpose of giving an elementary idea of the construction of the first British boats. Length, 63 ft. 4 in.; beam, 11 ft. 9 in.; height, bottom to superstructure deck, 12 ft. 1 in.; displacement, submerged, 120 tons.* Form of hull, cigar-shaped, but bluffer at fore-end—somewhat of the porpoise shape. Construction: all transverse sections circular. Plating: steel laid in ten strakes, $\frac{7}{20}$ in. forward and aft, $\frac{8}{20}$ in. amidships. Frames: 3½ in. by 3 in. by 7·8 lbs.; steel angles from frames Nos. 8 to 31 inclusive; other frames: 3½ in. by 3 in. by 6·6 lbs. Spacing of frames: 18 in. Stringers: 2½ in. by 2 in. by 5·9 lbs. steel angles. Bulkheads: 17½ lbs. per square foot, steel plate, amply braced. Deck beams: 3 in. by 3 in. by 6·1 lbs.; steel angles for machinery spaces and under torpedo-expulsion tube. Deck plates: 17½ lbs. per square foot to 15 lbs. per square foot. For comparison it should be noted that a steel plate 1 in. thick weighs about 42 lbs. to the square foot. Reverse frames are fitted to the floors in wake of machinery; the whole structure is tested to withstand the crushing pressure of water at a depth of 100 ft. The tanks are constructed of steel plates, and the system comprises forward and after trimming-tanks, main ballast-tanks separated by a longitudinal bulkhead, auxiliary ballast-tanks, gasolene tanks, etc. An electric storage battery is also installed in a water-tight steel tank.

* Light water-line displacement, 104 tons.

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The superstructure provides a clear deck space 31 ft. 6 in. by 4 ft. 5 in. with mooring cleats each side, also locker for anchor and cable.

Rudders: Two sets are provided, one pair in a vertical plane for horizontal steering and one pair in a horizontal plane for diving and rising, all of steel 10 lbs. to square foot, *i.e.* about ¼ in. of double plates, braced by arms from rudder-posts, which are of forged steel of sufficient strength to allow ample margin in case of excessive stresses. Conning-tower armour plate 4 in. in thickness, with an opening 21 in., closed by a water-tight hatch.

Propulsion: On the surface by a four-cylinder gasolene engine, each cylinder single action, and balanced to prevent excessive vibration, 160 H.P., 340 rev., one pint gasolene per H.P. per hour. Gasolene tank, 685 gal. Main motor propulsion submerged, electric 70 E.H.P., 800 rev. per min. Electric storage battery, sixty cells, chloride type, capacity of 1840 ampère hours at normal rate of discharge, and a capacity to furnish 75 E.H.P. for three hours at 120 volts. Propeller driven by 4-in. diameter steel shaft. Gearing is provided for the following combinations: main engine to propeller, main engine to motor (when motor is driven as dynamo to charge storage battery), motor to propeller, and motor to gasolene engine (for starting engine).

The actual speed attained with efficiency is 8 to 8·5 knots on the surface and 6 to 7 knots submerged. The ballasting and trimming system consists of two main ballast-tanks of 9 tons capacity, one auxiliary ballast-tank holding 3 tons, and one buoyancy tank of 600 gal., equivalent to the capacity of conning-tower. All these are filled direct from connections to the sea.

For longitudinal trimming one tank is located at each extreme end, forward and aft, arranged so that the horizontal trim is obtained by blowing water from one end to the other as required. A compensation system by water is provided for all weights expended or received. These arrangements keep trim of boat constant when discharging torpedoes, etc.

The air supply is provided by one air-compressor driven through gearing from the main engine or motor, furnishing air at 2000 lbs. pressure to storage flasks* made of steel, with a total capacity of 69 cubic ft.

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* Flasks stacked in groups on both sides of boat close to hull plating.

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A supply of low-pressure air is obtained from the 2000-lb. flasks through automatic reducing valves at 50 lbs. pressure, for use in charging the reservoir for firing torpedoes working the trimming system, and at 10 lbs. pressure for blowing out the ballast-tanks; by-pass valves are provided for increasing this pressure on emergency.

Steering and diving: Engines for this purpose, with reciprocating pistons attached directly to the leads, provide for quick movement of the rudders. The diving engine is fitted with automatic devices to maintain the boat in a horizontal position and secure constant depth whilst submerged. The coxswain operating the diving engine can reverse the diving rudders so as to rise or dive to greater depth, as desired.*

Manometers and gauges are provided for affording visual means of determining the condition of the boat in regard to depth of submergence, trim, condition of ballast-tanks, gasolene tank, air stored in the reservoirs, etc.

For navigating appliances a periscope † and compass are furnished, the latter in duplicate, one outside the hull, with reflecting tube for observation from the interior of the conning-tower, both being visible at all times to the captain of the boat. The armament consists of one torpedo-tube fixed in the bow, opening 2 ft. below the light water-line. Five short or three long 18-in. torpedoes are carried, one being kept in the tube and the others stowed in trolleys on top of the battery tank.

All of the Holland boats are capable of manœuvring as surface craft when in the "light" condition, that is, with ballast-tanks empty. For submersion, the first operation is the admission of the water into the main and auxiliary ballast-tanks, in order to bring the boat to the "awash" condition, with only the conning-tower above water, and with about three to five inches of water between the hull and the surface. In this condition the boat may, of course, be navigated, using her electric motor, and when it is desired to totally submerge, she is carried below the surface by means of powerful horizontal rudders, a speed of from five to six knots being necessary to make a successful dive.

In certain minor details the boats differ from one another, but not to any large extent.

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* These steering and diving engines were fitted in the first Holland boats, but since have been replaced by hand-working gear.

† See Chapter XIX, on Periscope Navigation.

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As mentioned by Captain Cable, no torpedoes were fired from "No. 1" submarine, as she was temporarily completed without her armament; this somewhat delayed her final delivery, therefore the "Hazard," with "No. 2" and "No. 3" submarines, left Barrow for Portsmouth in the middle of 1902 with torpedo-boat "No. 42" to help convoy the boats.

This provided a tow for each submarine should either require it. Unfortunately the torpedo-boat was old, and the strain of towing a two-thirds submerged body was almost too much for her.

When approaching Milford Haven with "No. 2" boat in tow, with a high sea running between the islands off the entrance, the torpedo-boat's steering gear jammed. At first it looked as if the submarine was in difficulties, as she turned two complete circles over the towing hawser, the seas breaking heavily and at times covering her whole conning-tower. With hard a-starboard helm on the wheel it was found that the torpedo-boat's head kept coming round to starboard towards the shore—a somewhat unusual predicament, to say the least of it. Stopping was out of the question, as the sea would have bumped the submarine into the torpedo-boat; this would not have hurt the former, but the surface-boat might have been sunk had the sharp beak of the submarine entered her flimsy side.

A jib was then fixed up with an awning; this kept the boat's head off to port until the damage to the steering gear could be localised, a fitting example of the old science being called in to aid the new.

The torpedo-boat's mishap was the only unpleasant incident during our first passage with these somewhat novel-looking craft. The weather at the start was most unfavourable, but the submarines proved themselves thoroughly good sea-boats in moderate weather.

The first two submarines were taken to Portsmouth, where they were joined some months later by Nos. "1, 4, and 5." Rather an amusing incident occurred at Holyhead. The boats had been taken in tow during the night before arriving, and in coming to an anchor, no sign of anybody stirring could be seen in "No. 4."

The Inspecting Captain of Submarines became alarmed; a pulling boat was manned on board H.M.S. "Hazard" with a party to break open the conning-tower should it have been necessary. Everybody wore a most anxious look that early morning, all fearing something must be the matter, as no sign of anybody moving in "No. 4" could

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be seen on the rescue party getting closer and closer. The boat finally pulled alongside the submarine, and the occupants beat her deck with a stretcher. After a few seconds up popped the head of the captain of "No. 4." "What in the —— is the matter? Is everything all right?" "Yes. Why, sir?" "Oh, we have been anchored half an hour, that is all!"

The Inspecting Captain was so relieved that he quite forgot to reprimand the young lieutenant for letting everybody go to sleep, and went back to the "Hazard" with a somewhat relieved expression on his face.

Manœuvres in the early part of 1904 were carried out against the home fleet to show the capabilities of the submarines in protecting the entrance of a port, and also for studying the mode of attack, and if possible to evolve some method of neutralising it. In the first series of experiments the submarines were masked by destroyers, who guided them towards the battleships. As soon as the latter were within a prearranged distance, the destroyers, having the greater speed, declined the attack, and left it to the submarines to press home. The press reports of this manœuvre declared that four battleships were torpedoed. Whatever the result was, it showed the new craft could, under certain conditions, prove extremely formidable. This success was merely an echo from across the Channel, where the French had proved, several years before, that submarines were unbeaten for coast defence. Further experiments were carried out against destroyers; as in the former case the submarines completely held their own.

The moral of these manœuvres clearly points to the fact that it will be extremely injudicious for battleships and armoured cruisers to risk themselves off any hostile port in which there are submarines.*

The Admiralty policy in ordering five boats was adversely criticised in more than one quarter, therefore it is not out of place to mention here that these small Hollands have proved most valuable in training officers and crews in the handling of underwater vessels (Plate 52). The experience gained in controlling the buoyancy of their boats enlarges the views of the officers in command in regard to freeboard. This must have the most beneficial results in the handling of above-water vessels, and is especially applicable

* *United Service Gazette*, June 4, 1904.

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to the management of destroyers, as, from practical handling of this class of vessel before and after submarine experience, the author ventures to offer the opinion that a submarine-trained captain of a destroyer would hazard much more than an officer without this experience in pressing a torpedo attack home on an enemy's ship, even if the weather was of the severest, and though holed in many places. The submarine officer knows what buoyancy is, and has a certain contempt for an excess of it.

This feeling perhaps may be better developed in those who, through a variety of causes, have during experimental work found themselves on more than one occasion with negative buoyancy and considerable downward momentum.

In the long series of experiments carried out day after day with the early Hollands in the Irish Sea, it became evident that these boats were too small for work in bad weather, chiefly because the conning-tower was low and had to be battened down in the slightest seaway; therefore, before the first order of five submarines was completed, the Admiralty and Messrs. Vickers, Sons and Maxim designed a larger boat embodying many new features.

In these plans much assistance was derived from the experience gained in the construction of the Holland boats. Money was taken in the naval estimates of 1902–3 for four of this large type of submarine. The first was launched in 1902 under the name of "A 1." The full details of design have been kept confidential, but what has leaked into the press show her to be of these dimensions:

Length . . .	100 ft.
Maximum diameter .	12 „ 6 in.
Submerged displacement	180 tons
Speed 11 knots on surface, 7·5 knots under water.	

In the first submergences in the Barrow Docks, "A 1" was a great success. It was well known that some foreign Governments had experienced considerable difficulty with their large boats, so this promising beginning with a 100-ft. boat was particularly gratifying to her principal designer.*

Subsequently in the Irish Sea the boat behaved exceedingly well and could be kept on an even depth-line at quite moderate speeds.

* Captain R. Bacon, R.N.

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PLATE 53.—*FOUR VIEWS OF "A1" SUBMARINE EXERCISING OFF PEILE ISLAND*, 1903.

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This was a great improvement on the "Holland" type, which have to be trimmed fine and kept at their utmost speed when being manœuvred under the surface.

Great interest was displayed in "A 1" submarine in these preliminary trials by the Lords of the Admiralty, who at various times visited Barrow. The Controller * on one occasion allowed his daughter to be submerged in this boat in the dock. When under water the mechanism was explained to her in actual working conditions, men were used as movable ballast to illustrate change of trim, etc. The submarine was kept a short time with the top of the conning-tower awash, the tanks were then blown and the boat brought to the surface.

In the acceptance deep-sea trials (Plates 53 and 54) several prolonged runs were made. Practically the submarine could have been kept under water for almost any time, and so pleased was the officer in charge of these tests that he offered the representative of Messrs. Vickers, Sons and Maxim to take "A 1" the next day from Walney Island to the Isle of Man under water, a distance of 45 miles. Unfortunately this offer was not allowed to be taken up, as the boat was then considered the joint property of the Admiralty and Messrs. Vickers; consequently she did not wholly belong to the firm, and therefore anything in the nature of an advertising run could not be considered.

These small incidents are mentioned for the sole purpose of showing the confidence that was placed in "A 1," a feeling shared equally by the second captain † of the boat and all the crew. The experiments carried out with "A 1" were legion; many new devices were tried for the first time, adopted or rejected according to how they worked out in practical tests. Plate 53 shows "A 1" running on surface, and Plate 54 when diving.

In all these preliminary trials, frequently going far into the night, the representatives of Messrs. Vickers were well supported by the naval crew, who were always ready to assist, as far as lay in their power, to make them a success.

The smartness of the bluejackets of "A 1" often drew forth praise from the firm; and on one occasion, when some of their employés were disabled in a battery gas explosion, a large number

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* Now Vice-Admiral Sir William H. May, K.C.B., K.C.V.O.

† Lieutenant A———.

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of workmen insisted on passing the hat round to collect money for rewarding the sailors who rescued their comrades. This kind action was very much appreciated, but had to be declined.

The boat, after carrying out this valuable experimental work, was taken to Portsmouth, and everybody interested thought she would soon make a name for herself, as the "Gustave Zédé" had previously done across the Channel.

In the manœuvres carried out in the early part of 1904 against the home fleet, previously referred to, "A 1" submarine, through slight defects in her gasolene engine, did not play an important part in the attack in which four battleships were claimed to have been torpedoed.

To investigate thoroughly the capabilities of the submarines these evolutions continued for nearly a week, and on conclusion of the day's work on March 18, 1904, it was noticed that "A 1" did not put in an appearance, and soon after 4 p.m. H.M.S. "Hazard" shaped course towards the Nab to look for her. As nothing of the boat could be seen in the vicinity of the entrance to the harbour, some anxiety began to be felt. When the gunboat arrived within about a mile of the light-vessel, right ahead was seen a large whitish area, some 20 ft. in diameter, where high air-bubbles were breaking and churning up the water. No doubt then remained as to what had happened, and the feelings on board the "Hazard" can readily be imagined when the sad meaning of those bubbles began to dawn upon each anxious searcher. A boat was lowered and pulled to the scene of the disturbed water to ascertain if the commotion was caused by the propellers still revolving. The occupants of this boat soon realised that air was very rapidly escaping from the air-reservoirs inside the submarine. Divers were all in readiness to go down, but the strong tide made it quite impossible for them to work that night. Sweeping operations were at once undertaken, and in a very short time a wire was got under "A 1"; this located her, but nothing more could be done until the tide slackened. The air continued to escape for about twelve hours in large quantities, which plainly showed the air-service had been opened up by one poor fellow before giving up the struggle.

The last seen of "A 1" in these evolutions was just before 2 p.m.; she was then lying a mile or so to the N.E. of the Nab light-ship. The "Hazard" was at that time close by the Warner lightship.

The "Berwick Castle," one of the Union-Castle mail steamers,

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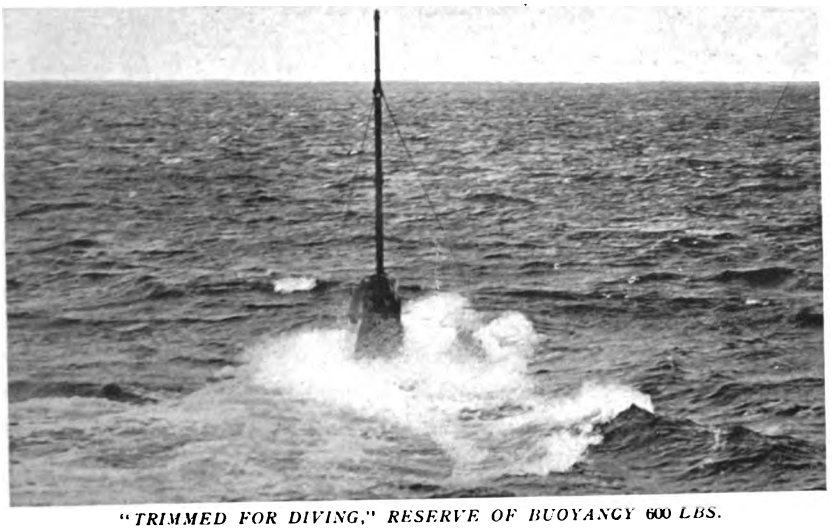
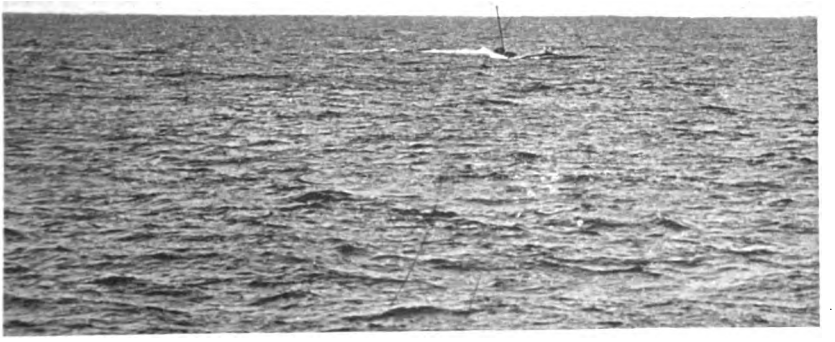
PLATE 54.—*SUBMERGED TRIALS OF "A 1" IN IRISH SEA*, 1903.



"TRIMMED FOR DIVING," RESERVE OF BUOYANCY 600 LBS.



"RISING" AFTER A SUBMERGED RUN.

RUNNING SUBMERGED, "PERISCOPE ONLY SHOWING."

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was noticed when off the Nab to alter course and hang about. No attention, however, was paid to her, and the mail steamer finally proceeded, and it was only afterwards recalled that she signalled reporting that a torpedo had struck her.

When "A 1" was lying on the bottom there was no difficulty at any time in passing hawsers under the hull and attaching them to lighters, but lifting nearly 200 tons dead-weight by this means was well-nigh impossible, and owing to the trend of the sea the hawsers again and again parted. After many attempts to raise the boat efforts were made to tow her into shallow water, but with no better success. The Commander-in-chief * then ordered regular salvage operations to be undertaken. These were placed in the hands of the Neptune Salvage Company of Stockholm.

Owing to bad weather and many unforeseen difficulties a considerable time elapsed before the salvage steamer was in a position to signal that the submarine was off the bottom. This led many well-wishers to write to the papers and urge the Admiralty to establish a naval salvage corps. "To persons familiar with salvage operations," wrote a distinguished member of the House of Commons, "it appeared extraordinary that a whole month was required to lift a comparatively small vessel, which, if she had been sunk in the Thames, would have been raised by the Thames Conservancy in three or four days." With all due respect to this writer, it may be open to question if his statement is quite accurate, when bad weather is taken into consideration; unfortunately for sailors, calm weather does not last long in the open sea. Those who have had the pleasant experience of picking up a battleship's six-ton anchor at Spithead well know the difficulties the divers have to contend against; only for a short time in slack water can they work. It is in many parts usually pitch dark with half a fathom of slime off the bottom, and five days out of six the weather during some part of the day is so boisterous that nothing can be done.

The contention that the Admiralty should have a fully equipped salvage corps, with suitable vessels, has much in its favour, against which may be placed the great expense of upkeep and, luckily, the difficulty of gaining experience.

Foreign salvage vessels work in all parts of the globe and obtain

* Admiral Sir John Fisher, G.C.B.

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most valuable experience in wreckage operations, etc. This field is closed to any but private enterprise.

At every dockyard port there are trained and skilful divers, also many vessels quite suitable for salvage operations. This case of "A 1" was quite exceptional and scarcely appreciated by everyone.

The conditions were these. A submarine, running with some few hundred pounds buoyancy, is struck by a passing steamer; the blow wrenches ajar the conning-tower, throws the boat on her beam ends and the steamer overrides the submerged vessel all along her bottom; water enters the aperture and soon destroys all buoyancy, causing the submarine to sink to the bottom. The crew are too damaged by concussion to stop the leak in the conning-tower hatch; the boat gradually fills with water and mercifully drowns the poor injured men.

The weight of hull, machinery, and water in the interior is just under 200 tons. This is far too great a weight for hawsers to lift in an exposed position without recourse to more scientific methods. The hull had to be first made water-tight, a matter of great difficulty, owing to the bad weather experienced; when this was completed, compressed air was forced into the interior to blow some of the water out, to relieve the dead-weight. As soon as sufficient water was blown out, the boat lifted, the hawsers were tautened, and, once off the bottom, very little time was lost in taking the wreck, suspended under a lighter, up Portsmouth harbour and placing it in dry dock.

The advisability of withholding the official report on the loss of "A 1" would be presumptuous for me to discuss in this volume. I may, however, state that the incorrect and unfortunate impressions produced by this lamentable accident were most regrettable. These were due to the grossly exaggerated comments that appeared in the press. None felt the unfairness of these criticisms more than submarine officers, and they undoubtedly wounded the relatives of my old friend and schoolmate, Lieutenant Mansergh,* deeply.

In some newspapers we were informed "A 1" was a most unsatisfactory diver; the officer in command was careless and failed to use his periscope. Then explosions from gasolene vapour, hydrogen gas, or chlorine occurred, but this was hushed up! In others, that an

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* Educated at the Royal Naval Academy, Gosport, Hants—Rev. E. Burney, M.A.

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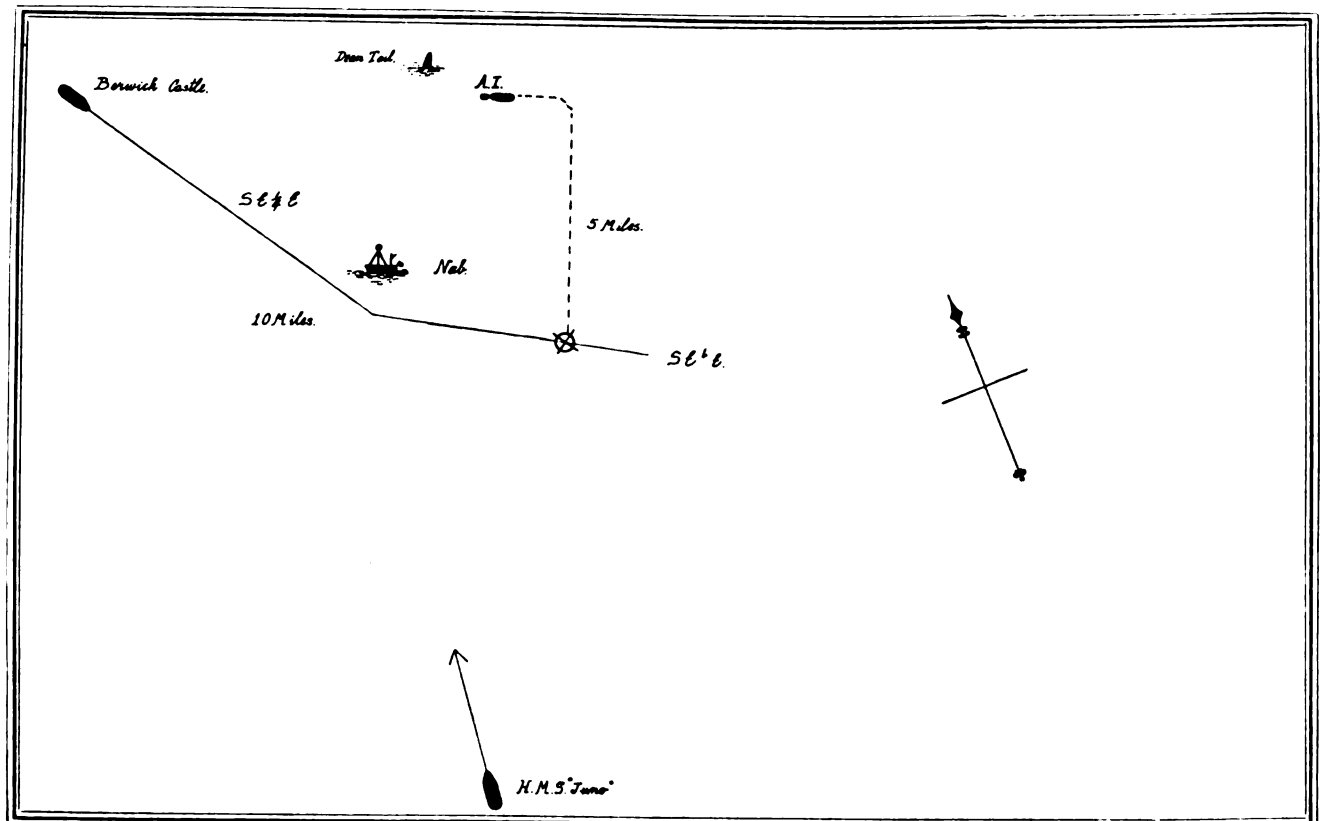

FIG. 27—*DIAGRAM SHOWING APPROXIMATE POSITIONS OF "A1" SUBMARINE AND S.S. "BERWICK CASTLE" BEFORE THE COLLISION*
(Not to Scale.)

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attempt had been made to dive under the "Berwick Castle," and only a few seconds lay between disaster and safety. Again, several of the crew were missing when the boat was opened up for examination. Mention was also made that fumes had stupefied the whole crew, and they were not responsible for their actions.

These deductions, and many more, were religiously copied in numerous foreign newspapers. Some American coloured illustrations the writer now has before him, giving details of this disaster, are nauseating to look upon.

With an intimate knowledge of "A 1" and her crew, I cannot refrain from offering a simple suggestion as to the probable cause of the catastrophe. It contains no mystery, as none exists.

In the exercises off Portsmouth, in which four battleships were claimed to have been put out of action by the submarines, the mishap to "A 1's" gasolene engine was a great disappointment to such an enthusiast as her captain, and made him all the more anxious that his boat should acquit herself creditably during the few remaining days of the manœuvres.

When the defect to the engines previously alluded to had been repaired, Lieutenant Mansergh seemed very pleased with "A 1," and having obtained permission from the Inspecting Captain of submarines to have a perfectly free hand in the next day's work, he was quite elated, and stated in the wardroom mess of H.M.S. "Hazard," the night before the accident, that he expected to do something with "A 1" on the following day, as she had never done so well as in some preliminary speed tests he had made after the defects referred to were repaired.

When off the Nab lightship on the day of the disaster I have no reason to doubt that the "Berwick Castle" was seen by this officer when some considerable distance off, and appeared as if she was coming directly towards him (Fig. 27) as he lay nosing the tide in an awash condition trimmed for diving. The last of the west-going stream was making, which would have caused the submarine to be lying roughly with her head in an easterly direction.

The "Berwick Castle" then appeared nearly right astern, as shown in diagram. Now in looking at a ship on this bearing, as all officers of small torpedo craft well know, it is exceedingly hard to estimate within two points (22½°) how she is steering, except by closing her. Even in large craft an accurate estimate of a ship's

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course within two points is no easy matter, unless bearings are taken and a time interval allowed to elapse between the observations; with the submarine, whose function essentially lay beneath the surface of the water, bearings were out of the question, as H.M.S. "Juno," coming from the southward, was to be thwarted by an invisible opponent in her attempt to force a passage by way of the Nab Channel. Lieutenant Mansergh presumably dived his boat and went at easy speed under water in the direction he knew the "Juno" would make her attack from, the steering being done by compass, the idea being to place himself without being seen within torpedo range of the cruiser before she reached the Nab.

The submarine in the exercise of her duty was running under water without even the periscope showing above the surface, as the captain was determined to make this attack successful to the best of his ability, and therefore gave no chance to the look-outs of the cruiser in their efforts to locate his boat.

The field to the southward appeared quite clear when the dive was made, the "Berwick Castle" being then a considerable distance off on the submarine's starboard quarter, and appearing as if she would clear astern of her. Consequently there was apparently no undue risk in running with nothing showing on the surface.

It has been mentioned the last of the west-going stream was making on the surface; this the captain of the boat knew from his tide-tables. Under the surface, at a depth of 25 ft., the tide may have been slack or even turned with a counter-current making to the north-east. This would cut the submarine's speed down from, say, 6 knots to 5 knots, and she would therefore be covering the ground at a slower rate than estimated.

The "Berwick Castle," coming up at a speed of about 10 knots, altered course slightly off the Nab for the Owers; this course is about south-east by east, her previous course being south-east a quarter east or so. Soon after steadying on the new course the liner felt two or three bumps; the main engines were stopped, and careful scrutiny of the surface revealed nothing, and after hovering about she proceeded, at the same time making a signal to the nearest warship, reporting a torpedo had struck her.

That these two vessels, following their call of duty, one submerged and the other on the surface, should come into contact at that psychological moment is surely what the coroner in bygone days

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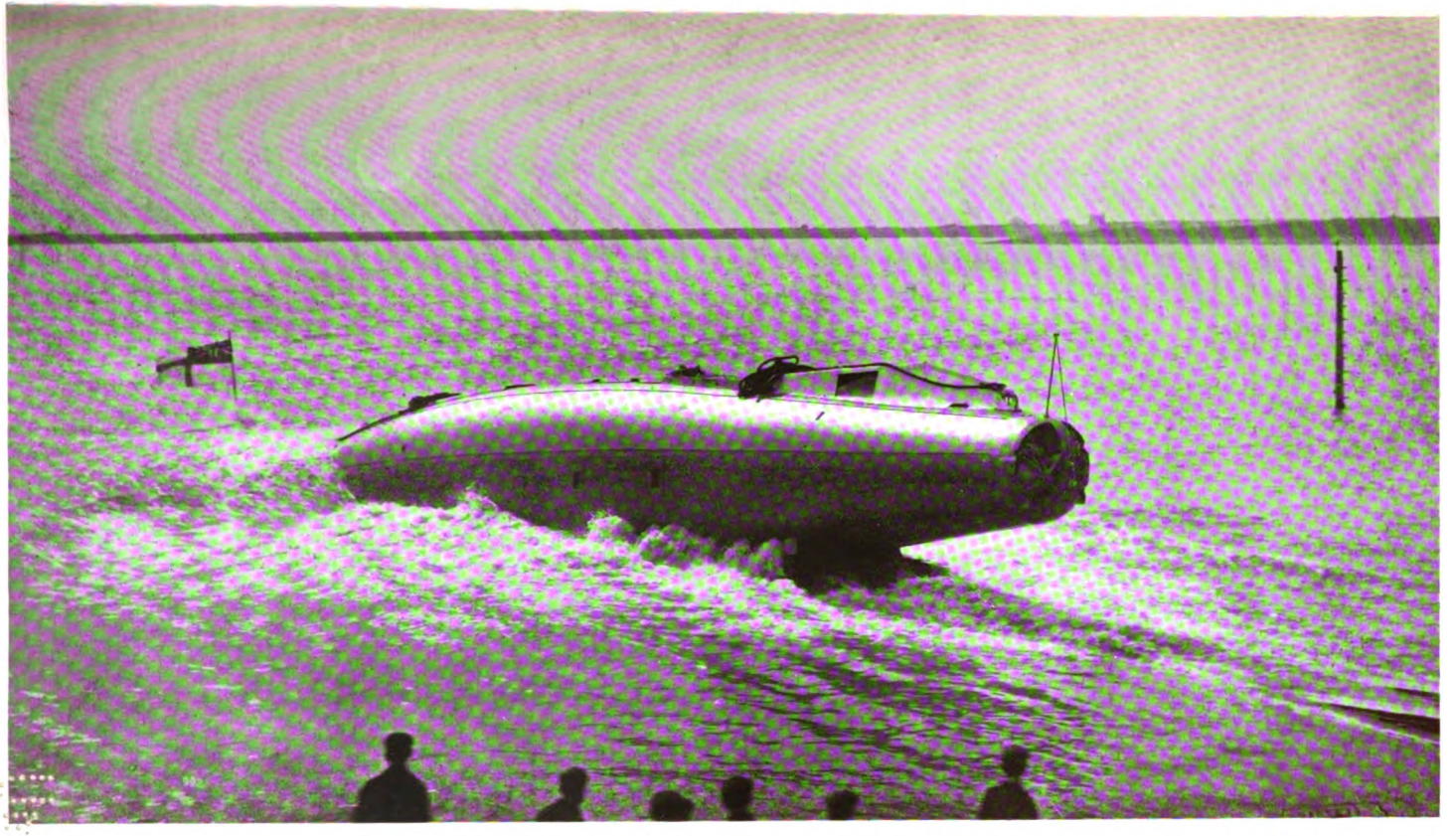

PLATE 55.—*LAUNCH OF "A 2" SUBMARINE.*

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would, in his summing up, have described as "the accident can only be attributed to the hand of God."

This explanation of the accident may be faulty, but is put forward against the speculative deduction that Lieutenant Mansergh neglected to use his periscope, and the unseamanlike assumption which stated that a boat of large diameter and high conning-tower was supposed to have been dived under a big liner in nine fathoms of water, which suddenly came into the field of her periscope.

In the author's opinion there is no shadow of doubt that this capable officer and his crew met their end through a combination of circumstances that we occasionally see most marked in catastrophes of an uncommon nature, and which we are unable to attribute entirely to the human element.

Stress must be laid on the fact that a submarine boat, carrying out manœuvres anywhere along the south coast of England, cannot possibly run away from every vessel that may appear on her horizon, otherwise she might as well return to port and stay there. During manœuvres slightly extra risks * are always run by torpedo-craft officers to make their part of the operations a success and so enable senior officers to obtain results as nearly approaching actual war conditions as possible. This prevalent idea was markedly alluded to by Rear-Admiral Sir C. Campbell, in a paper he read † at the Royal United Service Institution *à propos* of exercising our country's naval force, thus :—

"During this time the manœuvres cannot be too real, and even risks must be run in order to ensure high tactical training and skill."

Lieutenant Mansergh thoroughly appreciated what was expected of him, and, proud to be chosen for the command of his country's newest submarine, he was exceedingly keen on his work, and looked

* The loss of the destroyer "Ariel" whilst carrying out searchlight experiments for the military authorities at Malta, April 1907, brings home to both services the risks torpedo-craft officers are called upon to run. Nearly all these accidents have a certain value. Nothing could have surpassed the handling of the destroyer "Bruizer" in the many attempts made by her captain to take the injured vessel in tow. On all the towing hawsers parting, the "Bruizer" was, regardless of the heavy sea and shoal water, placed alongside the "Ariel," and succeeded in rescuing all the crew, except the captain and torpedo coxswain. The former was, when in a very exhausted condition, saved by Lieutenants Rawson and Sayers, of the Royal Garrison Artillery, but the coxswain paid for his devotion with his life.

† May 1906.

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forward to the day when he would be in command of a flotilla of these boats; as a first-class seaman he was second to none, and after having previously done good work in "No. 5" Holland and some experimental work in "A 1," his promotion to commander at an exceptionally early age was practically assured. The second in command of "A 1" was Sub-lieutenant Churchill, a young officer of great promise, who had been brought up in all the traditions of the service, as those who are fortunate enough to have a father an admiral can be. A wise hand had guided his early career and pointed out the work to take up, with the result that, in the examinations for lieutenant, he had taken five first-class certificates.

The bluejacket crew of "A 1" have been alluded to as having won much comment by their smartness at Barrow. They were all carefully picked men and the type that an officer trusts his life to, as they do theirs implicitly to him. We feel quite certain that the chain of circumstances, if it could be pieced together, would not show one single defective link that the officers or men had worked, and which brought about such a serious loss to the service. At Barrow Mr. Pretyman * had been shown all over "A 1" and took particular interest in our work, and when alluding to accidents in submarines in the House of Commons said: "The submarine, so far as the Admiralty experience went, was no more liable to accident than any other class of vessel. But when an accident did occur, the consequences were infinitely more disastrous; and it followed that special care should be taken to avoid accidents whether from the construction or the management of those vessels. It was always the most forward, the most enterprising, who volunteered for this service, men whom the country could ill afford to lose, and in these grievous accidents those who had suffered had just as much laid down their lives for their country as if they had fallen in action."

This tribute to the captain, sub-lieutenant and crew of "A 1," and all those who have since given their lives in this branch of the British Navy, is most richly deserved.

To conclude this sad topic, we may say that the loss of "A 1" was the result of pure misadventure and not the outcome of any inherent defect in the construction of this boat, nor in any oversight on the part of the captain or his crew.

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* Parliamentary and Financial Secretary to the Admiralty, 1905.

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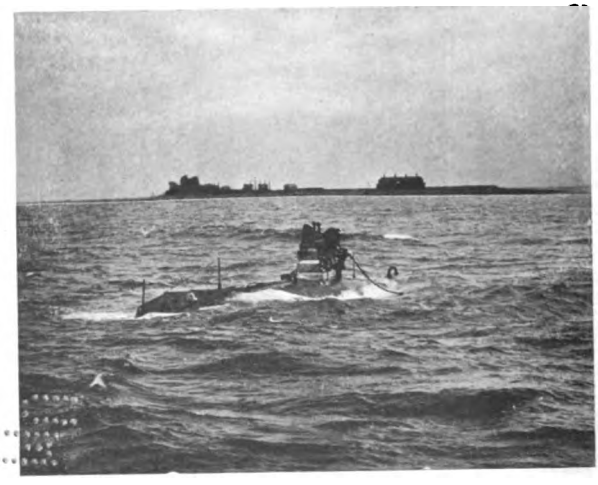
"RUNNING FULL SPEED."

"IN TOW."

"TRIMMED FOR DIVING."



"BEING TAKEN IN TOW."

PLATE 56.—*FOUR VIEWS OF "A2" SUBMARINE.*

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Following "A 1" submarine, three boats, "A 2," "A 3," "A 4," were laid down in the beginning of 1902. These were of almost the same dimensions as "A 1." The form of hull was improved, so as to give better speed, and the armament was increased by one torpedo tube. These alterations brought the surface displacement to slightly over 180 tons, and when submerged to about 200 tons.

In connection with the launch of "A 2" submarine (Plate 55), it is an interesting coincidence that the christening ceremony at the shipyard of Messrs. Vickers, Sons and Maxim, Barrow-in-Furness, was performed on April 16, 1903, by the only daughter of the late Lieut.-General Sir Andrew Clarke, R.E., who, as Inspector-General of Fortifications, had so strongly advocated, nearly twenty years previously, the adoption of submarine boats in this country.

In his memorandum of April 1885, when our relations with Russia were strained and war seemed imminent, after taking stock of our defences and making various suggestions, Sir Andrew Clarke recommended with his other proposals that £20,000 should be provided for a submarine boat. In the autumn of that year the trials of the Nordenfelt boat took place at Landskrona in Sweden.

The Inspector-General of Fortifications, with his staff, witnessed these trials, and on their return Sir Andrew Clarke recommended that Mr. Nordenfelt's boat should be purchased for a thorough investigation into the whole question of submarines to be made by searching and systematic experiment. To this recommendation the Government turned a deaf ear.*

The internal-combustion engines † of the "A" type are made chiefly by the Wolseley Co., and have twelve cylinders which develop about 600 B.H.P. on the surface; a speed of 12 to 13 knots is obtained when all cylinders are exploding regularly. During the manœuvres of 1904 the "A" class were stationed at Milford Haven and, with the Holland boats, carried out some good work. In 1903 nine more of the "A" class were laid down, "A 5" to "A 13."

After the unfortunate collision of "A 1" submarine with the "Berwick Castle," steps were at once taken to introduce a water-

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* Extract taken from *Life of Lieut.-General the Hon. Sir Andrew Clarke, G.C.M.G., C.B., C.I.E.*

† See Chapter XVII, on Motor Power on the Surface.

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tight hatch at the bottom of the conning-tower, so that if damage occurred to that part of the boat it could be at once cut off from the main hull.

In the provision of this second hatch a necessary precaution was taken, which was well demonstrated when "A 9" came into collision with the coasting steamer "Coath" off Penlee Point, Plymouth Sound, during some evolutions in February 1906.

The submarine was near, and actually attacking the cruiser "Theseus," the press reports state, when the collision took place; fortunately the blow was a slanting one and only had sufficient force to bulge the conning-tower slightly, do some small damage to the fair-water, and bend the periscope. We may assume the boat was placed in an awkward angle by the concussion, and if any water came into the conning-tower the lower door confined the inrush to that portion of the boat until the surface was regained.

If Plates 56 and 57 are referred to, the high conning-tower as first introduced in "A 1" can be seen, also a small flying bridge fitted up abaft all. This is a convenience that allows the crew to come up one or two at a time to obtain a blow of fresh air, and provides a convenient conning position for the captain and coxswain when running on the surface.

The bridge is made collapsible so as not to interfere with the boat's speed when running under water. Right aft is a curved pipe some 8 inches in diameter; this is the exhaust-pipe for the combustion engine. For submerged propulsion electric accumulators furnish the energy for driving the motors coupled to a single propeller. The under-water speed obtained is 8·5 knots.

Further manœuvres have been carried out with the "A" class off Tor Bay, Lyme Head, etc. Torpedoes fitted with collision heads have been fired at cruisers during these operations, and the percentage of hits has been distinctly encouraging.

An amusing incident occurred in the summer of 1905 at Tor Bay. A fishing party consisting of a yachtsman and two ladies were trawling in a part of the bay, which they considered quite secluded and safe from the submarines then operating in those waters, when suddenly one of the boats' periscopes appeared on the surface in such close proximity to the yacht that the submarine fouled the trawl and carried the yacht along with her until the trawl warp was cut and the submarine went off with the net, which

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PLATE 57.—*SUBMARINE "A 3" RUNNING AT FULL SPEED ON THE SURFACE.*

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was subsequently returned to the yachtsman with profuse apologies for interfering so abruptly with his day's sport, and causing his guests alarm.

To reduce such mishaps to a minimum further precautionary directions were issued in the *London Gazette* of May 18, 1906; these are as follows:—

"Notice is hereby given that submarine boats are being constantly exercised in the vicinity of Spithead, Sandown Bay, and Plymouth Sound, and in view of the difficulty that passing vessels have in observing these boats, and in order to minimise the risk of collision, it is considered advisable to establish an easily recognised signal by which approaching vessels may be warned of the presence of submarine boats. In consequence, therefore, of this decision, a large square red flag will in future be displayed from the vessel (usually a destroyer or torpedo gunboat) in company with the submarine boats when they are being exercised; and this will be shown whenever submarines are practising in the waters of the British Islands. The vessel displaying the red flag should be given, if possible, a berth of at least one mile. When this from any cause cannot be done, the vessel showing the red flag must be approached at slow speed, and a good look-out kept until the approaching ship can be warned by word of mouth of the danger zone."

Also orders have been given for the letter "S" (a blue and yellow triangular flag) to be flown by the semaphore tower in the dockyard, by the "Mercury," and at Fort Blockhouse, whenever submarine craft are leaving, entering, or manœuvring in Portsmouth harbour. This order appears to have been issued in consequence of the collision which took place on August 21, 1906, between submarine "B 4" and a dredger, and is an indication for other vessels to keep clear of submarines under way.

Considering our somewhat limited experience of submarines, it is more than gratifying that Queen Alexandra and Princess Victoria* went into the interior of "A 3" and had all the mechanism explained to them. This, so shortly after the loss of "A 1," was a great proof of the interest the royal family take in the latest developments of the navy. Few people are aware that the Prince of Wales has been for a lengthy submerged run in one of our early submarines. As

* March 1905.

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an old torpedo-boat officer, we feel sure this trip must have had more than a passing interest for his Royal Highness.

"B" Class.

The submarines of the "B" class (Plate 58) represent a new departure in this type of weapon and embody many improvements that have been made in every direction based on the actual experience gained with the early boats.

If the illustration, Plate 61, is compared with that of an "A" class boat, it can be readily seen that a superstructure has been placed on the bow; this is a great improvement for surface running, as the bow wave that massed on the fore-end of the Hollands and "A" class is to a certain extent dispersed.

These boats are 150 ft. in length with a diameter of 13 ft., and have a displacement of some 280 tons on the surface and 300 tons submerged. The internal-combustion engines are 12-cylinder Wolseley petrol type. These, compared to the early designs, show many improvements and develop close on 850 B.H.P.

The surface speed obtained under most favourable conditions is 13 knots and a submerged speed of 9 knots.

In the naval estimates of 1904 ten of this type were laid down, all of which have now joined up with the Portsmouth and Plymouth submarine flotillas.

"C" Class.

The "B" type, having proved so successful in practical work, will form a useful standard upon which future designs can be built up.

The "C" class (Plate 59) have a few improvements on the "B" type, their chief features being, length 150 ft., diameter 13¼ ft., displacement 300 tons, speed on surface 14 knots, and when submerged 10 knots. The extra speed is obtained over the "B" boat by introducing two propellers, as was noticeable in the French submarines designed by M. Laubeuf. Two periscopes are provided, one for the use of the captain of the boat and the other to allow a look-out man to continually sweep the horizon and give timely warning of any surface vessel coming within the field-glass of his instrument.

Minor improvements are being made in the steering gear, as "C 6" has an electrical arrangement for working the horizontal rudders.

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PLATE 58.—"*B 4*" *RUNNING AT* "*FULL SPEED*" *ON SURFACE.*

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In the programme of 1906–7 provision was made for the construction of ten new submarines by contract and two by the naval dockyard at Chatham. This number was subsequently reduced to eight to satisfy the general policy of retrenchment when the present Government revised the Cawdor shipbuilding programme and cut down expenditure on the navy by some £2,500,000. The boats in this revised programme will be all on the "C" design, with one experimental boat, with probably a better torpedo armament.

The terms of agreement entered into between the Admiralty and Messrs. Vickers, Sons and Maxim over the first order of Holland boats has now expired. Consequently submarines are now appearing in the programme of new constructions at the royal yards.

Chatham is the first dockyard to be connected with building these new vessels, and it is understood the two boats of the "C" type now completing will be ready for trial before the end of the present year 1907–8.

"D" Class.

The provision in the 1907–8 estimates is sufficient for laying down twelve submarines, but the exact number will depend upon the result of the experiments—which are well advanced—with the "D" boat. This type will embody certain improvements on the "C" class by having larger displacement, better form for surface and submerged work, greater horse-power, more speed, and certain improvements in the electric accumulator battery, with probably a more efficient torpedo armament.

Tabulating our submarines we now have the following number:—

	Programme.	Where built.	Numbered in order of building.*
5 of the "Holland" type of 120 tons (Nos. 1 to 5) . . .	1901–2	By contract	Nos. 1–5
1 of 180 tons A 1	1902–3	,,	No. 6
3 of 200 tons, A 2, A 3, A 4 . .	1902–3	,,	Nos. 7–9
9 of 200 tons, type A (A 5 to A 13)	1903–4	,,	Nos. 10–18
1 of 300 tons, type B (B 1) . .	1903–4	,,	No. 19
10 of 300 tons, type B (B 2 to B 11)	1904–5	,,	Nos. 20–29

* Should the letters A, B, C, D be abandoned for purposes of nomenclature, it is understood that the boats will be numbered in order of building; this is not new, as "A 1" was always known at Barrow as "No. 6."

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	Programme.	Where built.	Numbered in order of building.
11 of 300 tons, type C (C 1 to C 11)	1905–6	By contract . .	Nos. 30–40
5 of 300 tons, type C (C 12 to C 16)	1906–7	,, . .	Nos. 41–45
2 of 300 tons, type C . . .	1906–7	Chatham Dockyard	Nos. 46–47
1 experimental boat, type D . .	1906–7	By contract . .	No. 48
10 new boats, type D . . .	1907–8	,, . .	Nos. 49–58
2 new boats, type D . . .	1907–8	Chatham Dockyard	Nos. 59–60

Though the modern submarine boat has not been tested in recent naval wars, the locomotive torpedo* with which she is armed has shown on many occasions its tremendous powers of destruction.

Assuming then that the under-water vessel is merely an invisible means of taking this weapon nearer to its target, it must follow that the standard of torpedo warfare is proportionally raised. The actual torpedo itself is not improved in efficiency, except that the method of discharge under water is far more reliable than an above-water discharge, and the crew operating all the mechanism have the advantage that they are protected by many feet of water through which no gun missile can penetrate.

In concluding the chapter on British submarines, which for obvious reasons cannot be as full as could be wished for, I should like to refer to those who are in a large measure responsible for the success we have obtained with our modern submarines—that is, the shipbuilders and marine engineers. One of our largest shipbuilding firms has been associated with the Admiralty in developing this new departure in under-water torpedo craft. All those who had the pleasure of working side by side with the firm's representatives in the first experiments well know that to them our success with the early submarine boats is largely due. In the launch of H.M.S. "Dreadnought" honours richly deserved were conferred on many as a recognition of great skill in designing and constructing a new type of battleship. Would it be out of place to hope that some day those civilians who have built up our submarine flotillas may receive fitting recognition for their devotion to duty in undergoing all the discomfort and risks in assisting to develop this type of war-vessel for naval purposes?

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* Chapter XXII.

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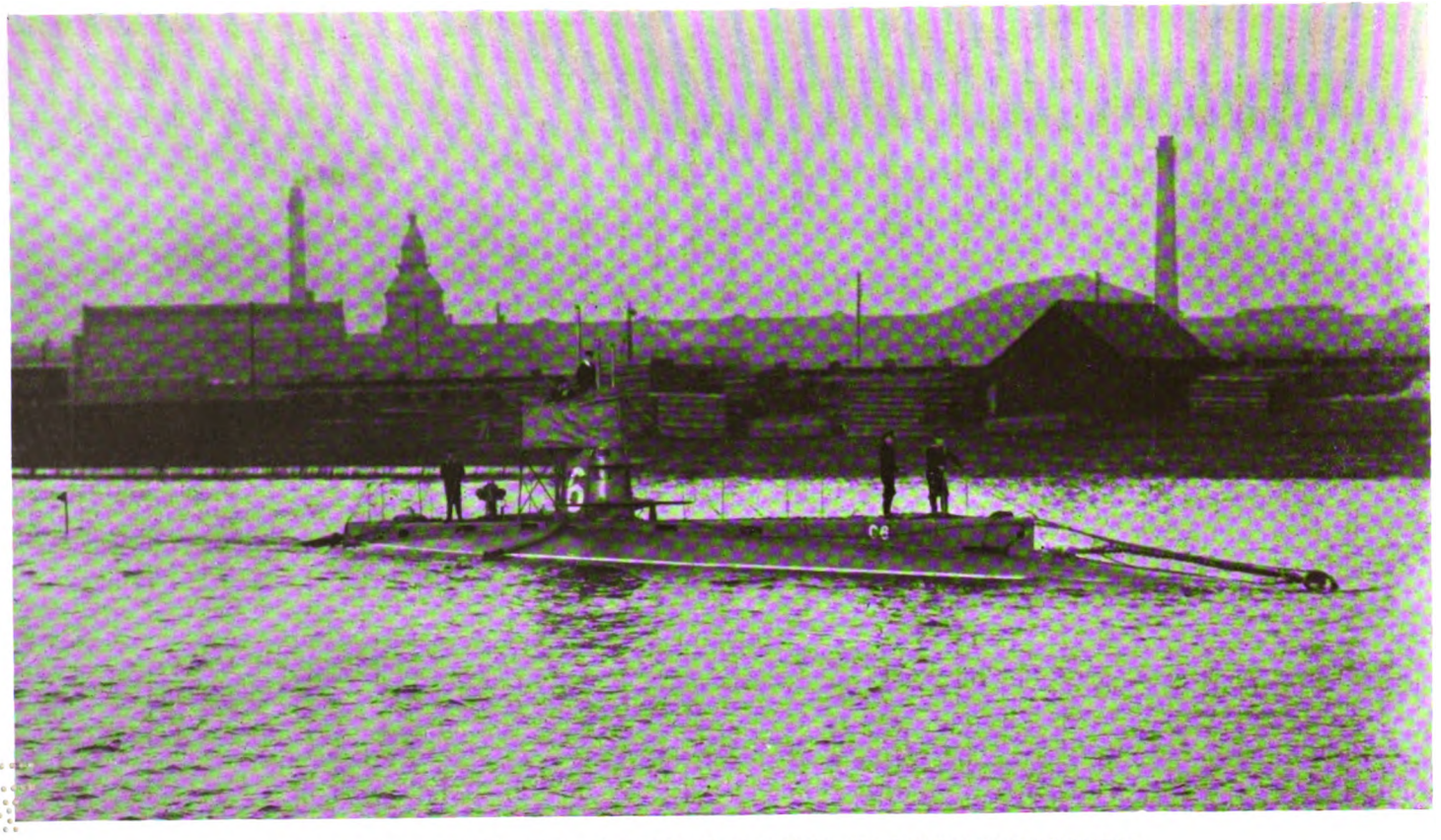

PLATE 59.—*SUBMARINE "C 6" IN THE DOCKS AT BARROW-IN-FURNESS.*

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CHAPTER XIII.

RUSSIAN SUBMARINES.

From the time Bauer* left Russian soil down to 1876 desultory experiments had been carried out on the Neva with submarines of various types; these led to no great advance until the attention of the celebrated Russian engineer, M. Drzewiecki, was drawn to submarine navigation. After careful study of the subject, a boat was designed and subsequently laid down, the hull being constructed of steel, with a length of 14 ft. and maximum diameter 5 ft.; the form is shown in Fig. 28. Water ballast, as usual, was admitted to overcome the buoyancy, and in this manner equilibrium was aimed at. The accurate balance between the weight of volume of water displaced and the weight of the boat was arranged for by working a piston in a cylinder. Small quantities of water by this means could be taken in or expelled, as the single operator desired. The boat was provided with a reservoir of compressed air for blowing out the water ballast. Arrangements were made to work the propeller by pedals, and off the shaft a pump could be driven for expelling the bad air.

A novel feature was introduced in the design, that enabled the operator, sitting with head in a glass dome, to place his two arms into fitted india-rubber sleeves and gloves. To use these sleeves at any depth air pressure was first pumped into them until the internal equalled the external pressure. When this equality was established it was thought the operator could attach a torpedo magazine to the hull of a hostile ship without much difficulty. On completion of this work the arms could be withdrawn. The explosive was fired by a clockwork mechanism releasing a firing bolt for striking a percussion-cap.

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* Bauer's Submarines, Chapter V.

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The preliminary trials of this boat took place at Odessa, and were so successful that the attention of the authorities was directed to these experiments.

The Russian Government, having had in previous times a leaning towards under-water vessels as weapons of war, took up the designs, and directed M. Drzewiecki to construct a larger boat. This led to a new submarine being laid down at St. Petersburg in 1879. The length of the old boat was advanced to 6 metres, with a maximum diameter of 2½ metres. Water ballast, as in the first design, was used for decreasing buoyancy. Arrangements were made for altering the trim by shifting a weight W, as shown in diagram, Fig. 29. The operators were increased to four, for working two propellers by a system of double pedals.

Compressed air was carried to replace the amount in the volume of air consumed by the operators, the vitiated air being pumped into caustic soda so as to free it from carbon dioxide (CO_2); this enabled the crew to remained submerged for several hours without any great inconvenience. A large circular dome covered the heads of the men and fulfilled the function of the conning-tower of more modern designs.

Two mine cases were carried in recesses on the upper part of the hull, and contained 110 lbs. of dynamite. These were supposed to be slipped when the boat was directly under the bottom of an enemy's ship, their buoyancy being considered sufficient to take them rapidly upwards and cause the spikes to become embedded in the hull of the vessel. The submarine, on getting clear, could fire the explosive by means of an electric battery and cable joined up to a fuse in the centre of the explosive.

Two rotary pumps were used for expelling water ballast, etc., and to reflect an image on the surface to those below an optical tube was fitted with prisms, and at the lower end spectacles were provided to aid vision through the periscope.

During the winter of 1879 many experiments were carried out in Lake Gatschina, and the boat frequently reached a depth of 15 ft., a speed of 3 to 4 knots being obtained. The Minister of War, after witnessing a series of performances with this boat, ordered fifty for coast-defence purposes. These small boats were worked by pedal and had only one screw.

The design provided eye-bolts at each end to allow the boats to

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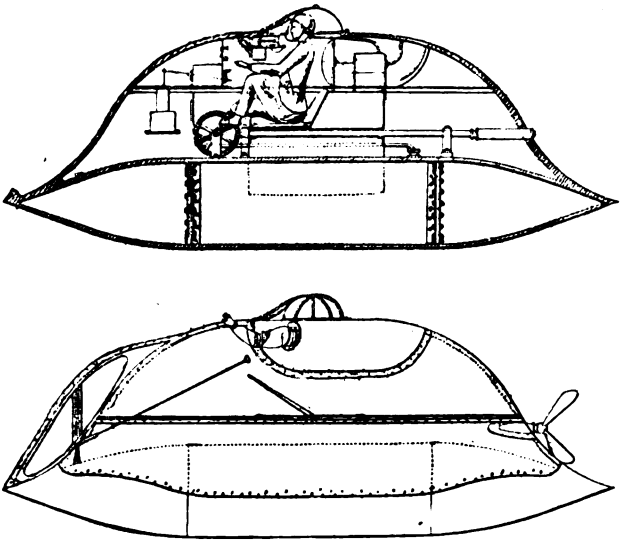

FIG. 28.—*M. DRZEWIECKI'S FIRST SUBMARINE*, 1876.

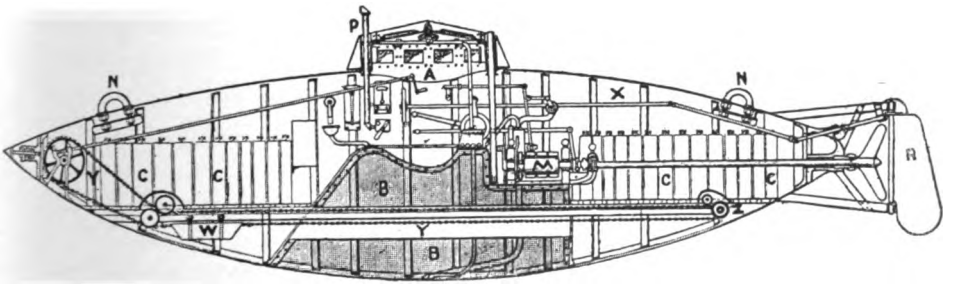

FIG. 29.—"*DRZEWIECKI II.*," 1879.

A few of this type were furnished with Electric Motive Power some years after completion.

A.—Conning Tower.
B B.—Water Ballast Tanks.
C.—Electric Storage Batteries.
M.—Electric Motor.
N.—Eye Bolts for lifting purposes.
P.—Periscope.
X.—Rods for working vertical rudder R.
Y.—Chain Gearing for working horizontal weight W.

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PLATE 60.—*RUSSIAN SUBMARINE, "PIOTR-KOSCHKA."*

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be hoisted at the davits of any ship for transporting purposes (NN, Fig. 29).

When electric storage batteries promised some success M. Drzewiecki modified one of his boats by installing a battery and motor for driving the propeller. By this method of propulsion the submarine was made to travel from 4·5 to 5 knots, at the same time permitting a reduction in the crew from four to two.

The chief fault of these boats was their slow speed, and on the defence of the coasts passing from the Minister of War to the Minister of Marine, the latter, after carefully examining all his resources, decided that these small boats were of no great value for defensive purposes, and therefore abandoned them, with the result that several were turned into buoys, ends of pontoons, etc. A few to this day can be seen utilised for such purposes.

In the competition of submarine designs opened by the French Minister of Marine in 1896 to all nations, M. Drzewiecki was naturally attracted, and became one of the twenty-nine competitors. His design had a displacement of 190 tons, and was to be propelled on the surface by a steam-engine with an estimated speed of 15 knots. For submerged work, electric energy was to be stored in accumulators. The boat's armament consisted of two torpedoes stowed externally in drop collars.* These special launching frames were adopted by the French Minister of Marine and placed in the "Narval" and many subsequent boats; M. Drzewiecki's designs of a submarine carried off the second prize in the competition.

Coming to more modern submarines, Plate 60 shows the "Piotr Koschka," built from the designs of Lieutenants Kolbasieff and Kuteinikoff, and launched in 1901. The dimensions are:

Length . . .	50 ft.
Maximum diameter .	14 „
Surface displacement .	60 tons.

The motive power is furnished by electric accumulators of the Bari type to two motors for rotating the twin propellers. On the surface a speed of 8 knots and submerged 6 knots is reported to have been obtained. The armament consists of two 18-in. locomotive torpedoes carried in Drzewiecki drop collars, as shown in the illustration.

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* See Chapter XXII.

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A sister boat, the "Forel," was constructed and sent out to Vladivostock before the commencement of hostilities, but as she never was properly completed, her value was negligible.

A submarine was constructed from the designs of Engineer Bubnoff, and launched in 1903 under the name of "Delfin," possessing the following dimensions :—

Length . . .	77 ft. 1 in.
Maximum diameter .	14 „
Displacement on surface	175 tons.
Submerged, about .	200 „

A Panhard petrol engine was provided for surface propulsion, giving a speed of 11 knots, and sixty-four electric accumulators furnished the energy for working the motors when submerged.

The armament consisted of four 18-in. torpedoes carried in Drzewiecki drop collars. In the first trials this submarine was quite successful, but in some subsequent work a large number of untrained men were allowed on board the boat for purposes of instruction, when she was lying off the Baltic shipyard at Cronstadt;* and as the kingston valves were being opened to demonstrate the system of submergence, the water came in somewhat too quickly, and what with the extra men on board, the boat suddenly attained downward momentum before the conning-tower hatch could be closed. In fact, it is reported that one of the men lost his head and prevented the hatch being closed in his efforts to escape; the result was that the boat sank to the bottom bow first, and unfortunately one officer and twenty-three lives were lost.

This regrettable mishap may be attributed to allowing a large number of untrained men in the boat, who were not under perfect disciplinary control—the one great essential in submarine work, and without which the most perfect under-water boat is valueless. The boat was raised, and is believed to have been sent to Port Arthur during the war, but it is doubtful if her destination was reached before hostilities were over.

The second contract for Lake submarines partly completed at Newport News, U.S.A., was shipped to Libau during the Russo-Japanese

* June 29, 1904.

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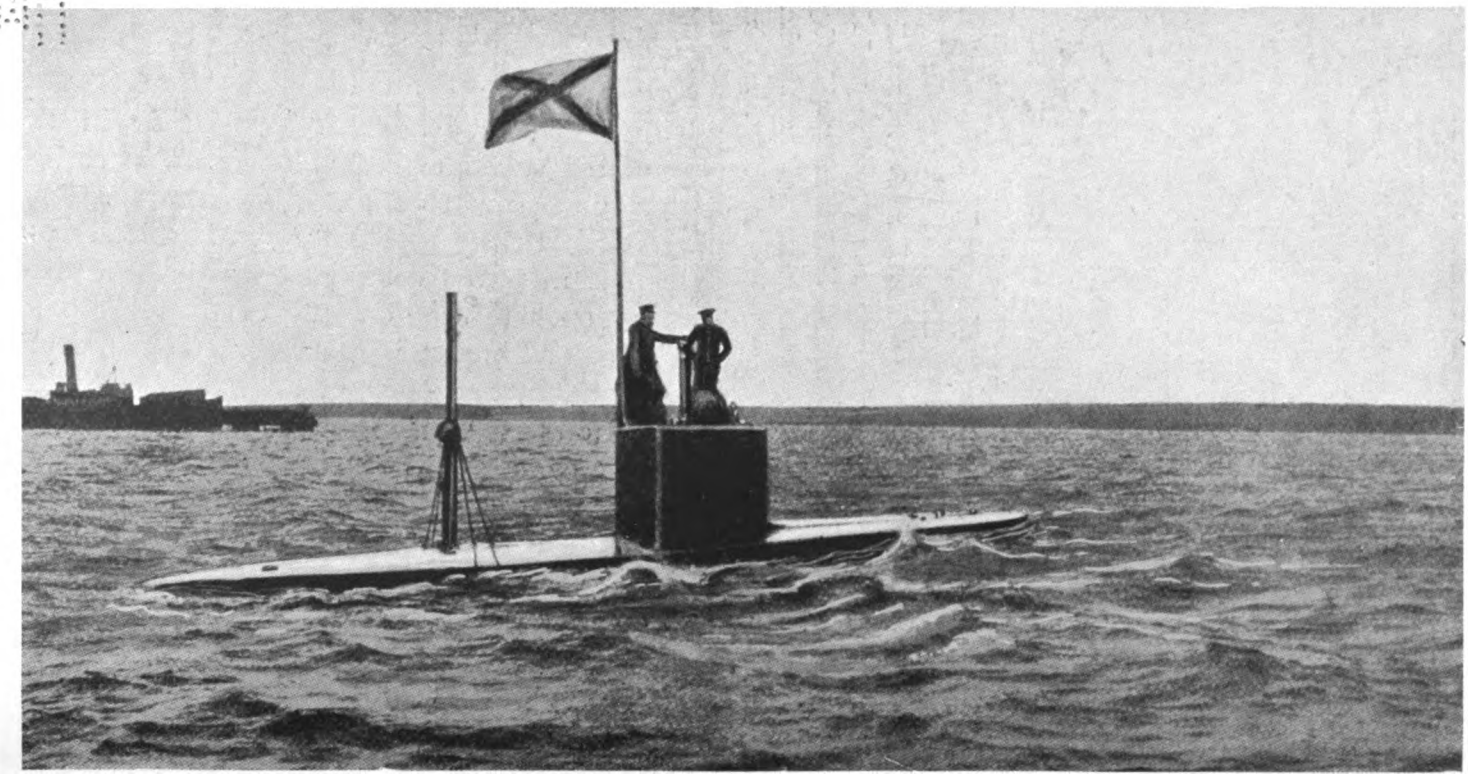

PLATE 61.—*A RUSSIAN LAKE SUBMARINE UNDER TRIAL AT LIBAU.*

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war.* These boats have now all been put through their acceptance trials, which included a 9-mile submerged run in the Baltic, and the hulls were tested at a depth of 126 ft. for half an hour (Plate 61).

In 1905 two of this type made under their own power the run from Libau to Cronstadt, a distance of 560 miles, in the severest of weather. The boats stood such a severe test well, and proved that the claims of the Lake Torpedo Boat Company as to the sea-going qualities of their boats were not unduly exaggerated.

It is understood that five of the "Lake" type were, at the commencement of 1906, in commission at Vladivostock, and several more of a similar type but of greater tonnage have been ordered for building up Russia's modern torpedo-craft flotillas.

Two improved "Delfins" have been constructed, and also two boats from the designs of M. Drzewiecki.

The work done by the Russian submarines during the war * was of a negative nature. The small "Forel" was the first boat sent to Vladivostock and was followed by several others of different types. The "Kastra," constructed at the Baltic shipyard from the plans of Engineer Bubnoff and Captain Beklemisheff, that was to do such wonders, was a perfect failure, and had erratic diving propensities. When with difficulty this boat was forced under water she usually stayed there for some considerable time, and could scarcely be induced to come to the surface.

The Lake boats that were sent out in sections were of little value, as the mechanics that arrived from St. Petersburg to put them together were oftener drunk than sober. When they were eventually completed some amusing incidents occurred. As the officers had not the faintest idea of how to handle these boats, breakdowns were rife. Three boats went for a short trip down the coast of Corea, but two had quickly to return, owing to the large number of defects, before they even sighted an enemy.

One boat was lost and another had a severe explosion. Captain Plotto assumed the direction of the submarines on his own initiative, but received scant encouragement from the Admiral at Vladivostock, so could do little. He however affirms that the mere fact of having several submarines at Vladivostock influenced the Japanese in deciding to defer their attack on that port.

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* Russo-Japanese war, 1904–5.

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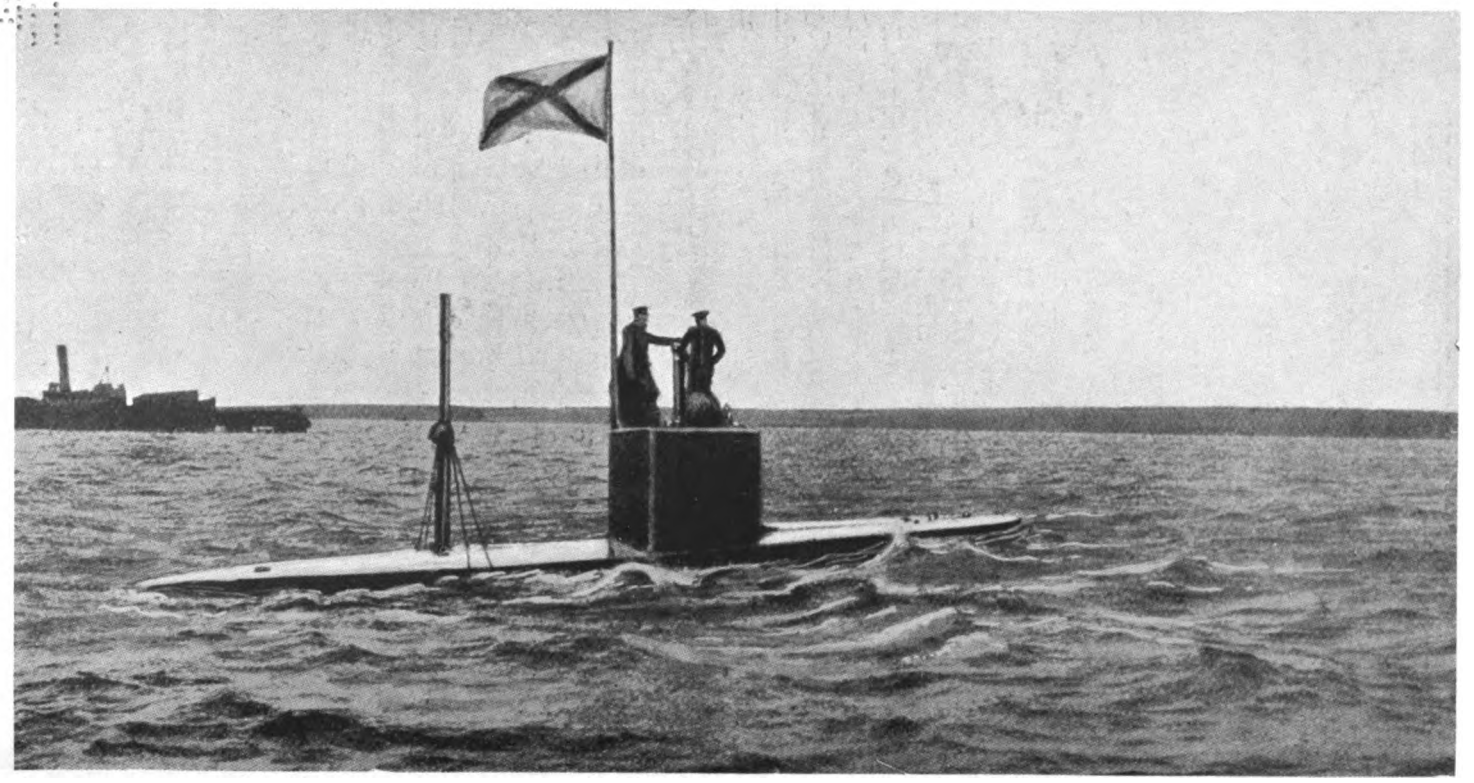

PLATE 61.—*A RUSSIAN LAKE SUBMARINE UNDER TRIAL AT LIBAU.*

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* Russo-Japanese war, 1904–5.

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CHAPTER XIV.

ITALIAN SUBMARINES.

In the beginning of 1892 we find Italy experimenting with the submarine "Pullino"—a boat designed by an Italian naval constructor on similar lines to the French "Gymnote." *

Her length was 40 ft. with a beam of 6½ ft. The crew consisted of four men. Some interesting experiments were carried out with this boat, under the supervision of the officers of the torpedo school depôt ship "Maria Adelaide," in Spezia Bay. Sufficient data was obtained from the results of these trials to warrant the construction of a new boat. This submarine was launched at Spezia, from designs of Naval Constructor Pullino, † in 1896, and given the name "Delfino" (Plate 62).

She was constructed of steel plates and of the usual spindle form, with a length of 78 ft., maximum diameter 9 ft., the surface displacement being 93 tons, and 102 tons when submerged. The energy for driving a motor coupled direct to the propeller was provided by 300 electric accumulators; this installation gave a speed of 6 to 6·5 knots on the surface and 4 knots submerged.

For submerging, two vertical screws were provided for forcing the boat under the water against a small reserve of buoyancy, in a similar manner to the system employed by Mr. Nordenfelt. Plate 62 shows the vertical propellers, one forward and one aft. A periscope also was used in this boat.

A series of fairly successful trials were carried out in her before Admiral Carlo Marchese, but these results led to no definite policy on the part of the Italian Admiralty in connection with these weapons of war.

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* Page 77.

† Late Director-general of Naval Construction.

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PLATE 62.—*ITALIAN SUBMARINE 'DELFINO" RUNNING AT FULL SPEED IN THE ROADS OF SPEZIA.*

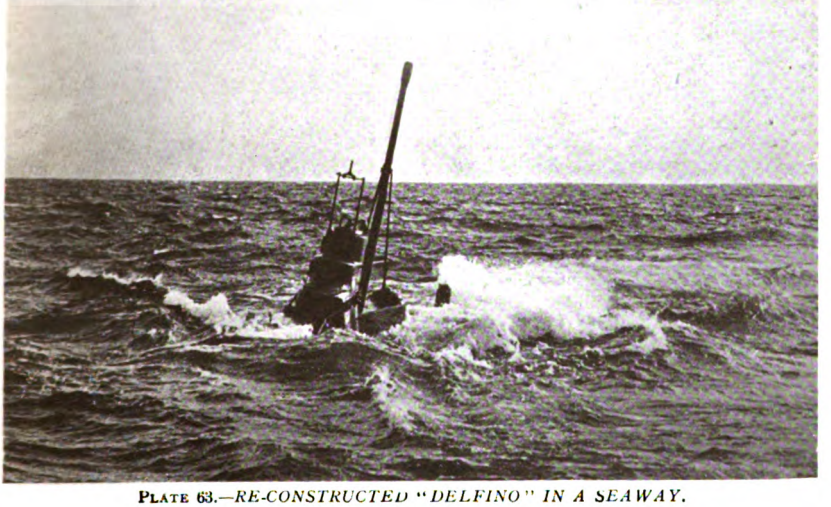

PLATE 63.—*RE-CONSTRUCTED "DELFINO" IN A SEAWAY.*

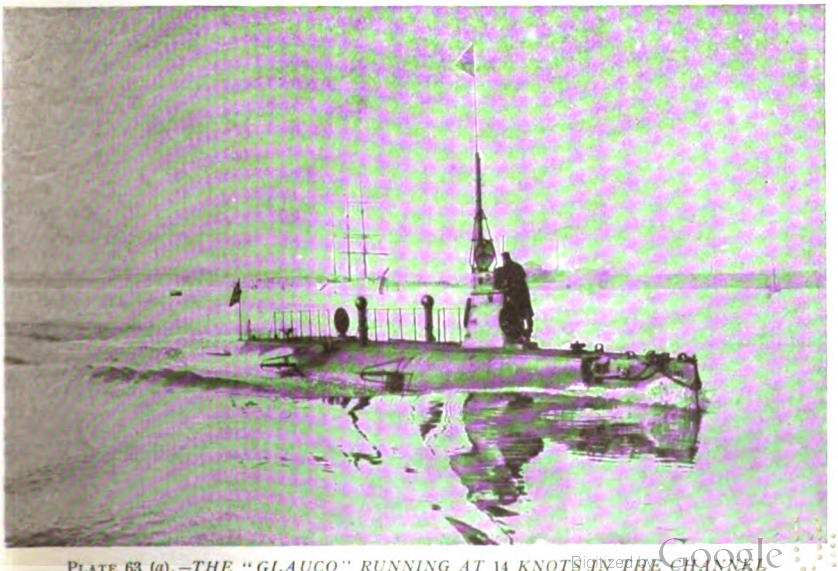

PLATE 63 (*a*).—*THE "GLAUCO" RUNNING AT 14 KNOTS IN THE CHANNEL OF THE LIDO*, 1907.

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In 1901 a small 58·8-ft. submarine was completed at Spezia, and launched under the name of "Tritone." As her design has not been repeated, we can presume she was no great success.

During the last few years more attention has been given to the value of submarines for coast defence, and in 1902 a lively discussion took place in the Chamber of Deputies. On this occasion members pointed out that their country was being left behind, and urged the Government to move in the matter.

Admiral Morin, then Minister of Marine, assured the deputies that every attention was being given to this question, and stated that new designs were under consideration which seemed likely to give good results, and that he had recommended that the submarines should be constructed in the royal dockyards and not by private firms, as was being done by some other nations.

The "Delfino" was overhauled, and as her speed was far short of what she was designed for, the order was given to completely reconstruct her as follows:—

Length	78 ft. 6 in.
Maximum diameter . .	10 „ 1 „
Displacement on surface .	104 tons.
„ submerged .	111 „

Motor, 150 E.H.P. giving a speed of 10·5 knots.
Armament, two torpedo tubes.

A new periscope, called the cleptoscope, has been fitted in the boat. This has a field of view of 60°, the diameter of the tube being 5 in.

As practically very little of the old "Delfino" was left, she may be regarded as quite a modern submarine (Plate 63); the only reason for retaining part of the hull was that money could be taken out of the navy votes for reconstruction, whereas the necessary amount for a new boat was at that time not forthcoming.

~~However, towards~~ the end of 1905 the boats ordered by Admiral ~~Morin began to show~~ signs of completion. The "Glauco" was launched at the Royal Arsenal, Venice, from designs of Naval ~~Constructor Cesare Laurente~~. It is interesting to note that this boat was christened not, as usual, with a bottle of wine, but by sinking a ring into the lagoon, as was the ancient custom at Venice, the idea being that the boat or ship was in that manner wedded to the

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Adriatic. Many ancient rings can be seen in the interesting museum of the arsenal. During the visit of the British Mediterranean squadron to Venice, in the autumn of 1906, the submarine "Glauco" was seen leaving the port. Plate 63 (a).

In appearance she is very similar to our "A" class boats, and noticeable as having only a small superstructure, high conning-tower with sighting-hood fitted with a periscope of the Russo-Laurente pattern, also hydro-planes for assisting the horizontal steering.

Her dimensions are:

Length	98 ft. 4 in.
Beam . . .	13 „ 9 „
Surface displacement	150 tons.

For surface propulsion a petrol motor is provided, and for submerged work the usual electric motor and battery of accumulator cells.

It was claimed by all the Italian officers, in conversation, that the speeds obtained by the "Glauco" are in advance of either the French or English boats of a similar kind, with not so much displacement.

The "Squalo" was completed shortly after the "Glauco" and is almost identical with the latter. These two boats, with the modernised "Delfino," took part in manœuvres against the battle fleet in the Ionian Sea towards the end of October 1906, and press reports state that the submarines showed their periscopes little and well demonstrated their utility.

The designer of the "Glauco" is supervising the construction of a more powerful boat, by a private firm * at Turin, for the Italian Navy.

Her dimensions are:

Length	137·8 ft.
Beam	13·3 „
Surface displacement . .	175 tons.
Submerged displacement .	220 „

Time for diving, five minutes from the surface condition.

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* Fiat-Muggiano Co., lately renamed the Fiat-San-Giorgio Co.

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Three sets of internal-combustion motors are to be provided, and it is anticipated a surface speed of 15·5 knots will be obtained.

The design allows of more freeboard than is usually found in submersibles, as in surface trim she will be 3 ft. 6 in. out of water. Her armament is to consist of two tubes for the discharge of 18-in. Fiume torpedoes, and two periscopes will also be provided of the Laurente-Russo type, for vision when submerged—one binocular with natural vision, the other monocular without an opaque glass, but with an enlargement; both instruments will have a field of 50°, and be 5 metres in length. In the Government yards the "Otaria" and "Tricheco," on the same lines as the "Glauco," are just commencing their trials.

Both these boats are fitted with petroleum motors of the Thornycroft type. The combined sets for each boat have been tested at the Chiswick works to 600 E.H.P.

Another boat, the "Narvalo," is nearly ready for launching.

At their shipyard at Spezia the Fiat-San-Giorgio Co. are now offering to build submersible boats for any nation. The specifications state that the submersibles would be designed of about 250 tons submerged displacement, with a length of 42·5 metres and beam 4·25 metres, the fuel to be used being either benzine or petrol, and the boat to have three propellers, each driven by two motors developing 720 HP. and giving a speed of not less than 15 knots on the surface. For submerged running tandem motors are to be fitted to each shaft, and provided with energy from electric accumulators having a capacity sufficient to keep up a speed of 7 knots for four hours.

The money taken in the 1906–7 Italian estimates makes provision for the construction of seven submersibles, but no decision has yet been arrived at as to what design is to be adopted for the new boats.

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CHAPTER XV.

SUBMARINES OF GERMANY, JAPAN, PORTUGAL, SWEDEN, HOLLAND, AND AUSTRIA.

German Submarines.

The contention that Germany does not need submarines owing to the large amount of shallow water on her coasts does not now have many supporters; in fact there is at the present time a considerable growth of sentiment in favour of submarine boats in that country. As far back as 1890 two submarines of the Nordenfelt type were built at Kiel and Danzig respectively. These boats gave very mediocre results during the time they were attached to the torpedo craft flotillas at Kiel and Wilhelmshaven. Their dimensions were:

Length	34·85 metres.
Maximum diameter . .	3·65 „
Surface displacement . .	212 tons.
Speed on surface . .	11 knots.
Submerged speed . .	4·5 „

Steam was generated and stored in a similar manner to that employed in the Nordenfelt design. In a semi-submerged condition these boats were moderately good, but their speed did not come up to expectations, and therefore the type was not repeated. Notwithstanding this want of success, German inventors still kept their eyes on the value of submarine boats, and a few years later a naval officer submitted designs of a new type. This boat was constructed at the Howaldt shipbuilding yard, Kiel, with these dimensions:

Length	47 ft.
Maximum diameter . .	9·5 „
Surface displacement . .	84 tons.

Armament, 1 torpedo-tube placed in the bow.

The motive power was furnished by electric accumulators for

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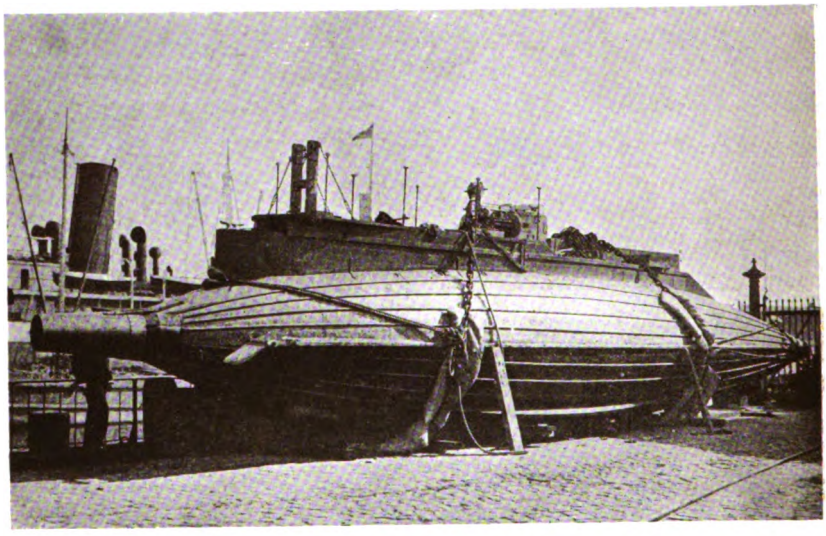

PLATE 64.—*GERMAN SUBMARINE CONSTRUCTED AT KIEL*, 1902.

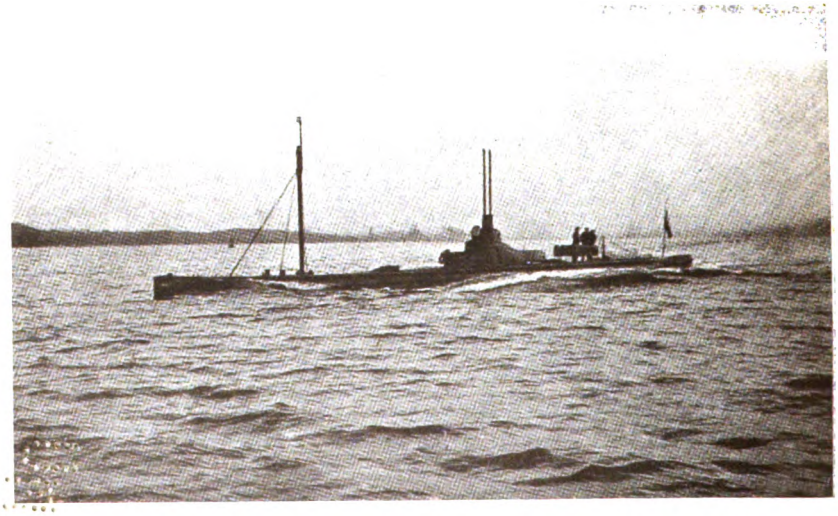

PLATE 65.—*THE KRUPP-GERMANIA SUBMERSIBLE of M. d'EQUEVILLEY.*

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driving a motor; this gave a surface speed of 6 knots and when submerged 4 knots.

The inventor was a torpedo lieutenant, and he apparently designed his boat on the lines of a locomotive torpedo, as shown on Plate 64.

On the top of the hull a long superstructure was built for over two-thirds of the entire length; about the centre of this was the conning-tower, with the usual ventilators, compass tower, etc. Horizontal and vertical rudders can be seen in the illustration placed right aft. The trials of this boat were conducted in Eckernförde Bay, but were not attended with much success. Towards the end of 1905 some considerable excitement was caused in France by a report that the "Aigrette" plans had been stolen and a submarine boat had been secretly constructed at Kiel to these designs. The French press naturally waxed eloquent, and stated that the seven years' labour of M. Laubeuf was completely thrown away. However, on some further investigation, it appeared that the plans of the boat were actually offered to the French Ministry, who declined them; so naturally the inventor, M. d'Equevilley, took his design to where a market could be found.

The boat was launched during August 1905 at the Krupp-Germania yard, Kiel (Plate 65).

Her dimensions are:

Length	116 ft. 8 ins.
Maximum diameter . . .	13 „
Displacement on surface . .	180 tons.
Submerged displacement about .	220 „

For surface propulsion a 200-H.P. petrol motor of the Körting* type is fitted to each of the two propeller-shafts. This arrangement gives a surface speed of 11 knots. The petrol tanks are placed in the superstructure outside the hull and contain a sufficient quantity for 1000 miles at 11 knots.

For submerged work, electric accumulators and motors are provided. The battery is capable of running the motors for three hours at a 9-knot speed.

The chief features of this boat are that the two periscopes, each with a field of 50°, can be trained in azimuth by electric motors,

* Details of this engine are given in Chapter XVII.

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and have a special erector fitted for giving the observer an upright image during rotation.

Three torpedoes are carried and can be discharged from a 45 cm. bow tube.

The time taken to put the boat in "diving trim" from the surface condition is five minutes.

Submarine "U 1."

Whilst the Krupp-Germania private submarine was under construction, a second boat was laid down by the same firm for the German Government; this vessel was launched on August 3, 1906, under the name of "U 1," with these dimensions: *

Length	101 ft. 3 ins.
Diameter	10 „ 1½ „
Surface displacement . .	200 tons.
Submerged displacement .	240 „
Speed on surface. . .	11 knots.
Speed submerged . .	9 „

The armament consists of one bow tube and three torpedoes.

Experiments with this submarine are now being carried out in Eckernförde Bay, where an electrical plant has been set up on shore for charging the accumulators.

There can be no denying the fact that Japan, during her late war with Russia, has drawn considerable attention to the science of torpedo warfare. She has shown to the maritime Powers of the world how to strike stupendous blows with the locomotive torpedo and offensive mines.

These lessons are not being overlooked in Germany, for we notice that country embarking in a very large programme of torpedo-craft construction, and there can be little doubt that in the next European struggle Germany will not rely so much on her mammoth battleships, but more largely on torpedo craft and mine-layers for carrying out the maximum amount of destruction at a minimum outlay.

Some people may argue that submarines are unsuitable for German harbours. This may be true; but it is generally recognised

* Details given by the *Globe*, September 1906.

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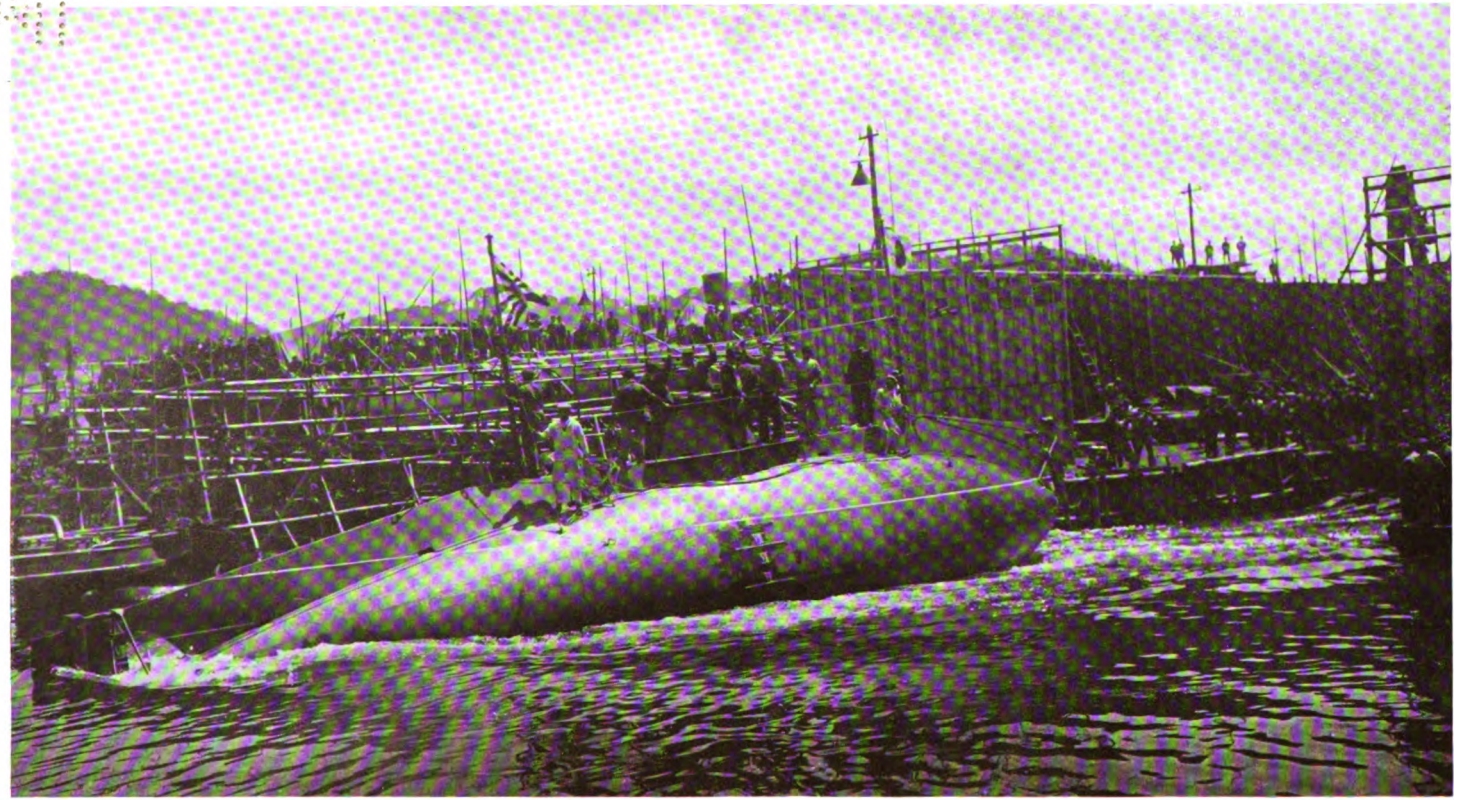

PLATE 66.—*LAUNCH OF JAPANESE HOLLAND "No. 1," 1905.*

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that in the expansion of Germany the Belgian provinces may be absorbed, and the difficulties about harbours will disappear.

In the 1906–7 German estimates it may be noted that £300,000 is set aside for submarine mines, and £250,000 for submarine-boat experiments, also the large sea-going torpedo-boats are to be increased to 144 in number.

Submarines of Japan.

In the history of modern navies nothing has been so remarkable as the sudden rise of the Japanese Navy.

The first British officers went out in 1867 to instruct the Japanese in the science of naval warfare; these officers were followed by many others, who may all now justly claim that their work laid the seeds which enabled Japan, in under forty years, to place herself in the very front rank of the naval Powers of the world. Where other nations have taken centuries to develop, this young Power has taken decades.

Amongst the instructing officers and students in Japan were several who had progressive ideas of a scientific turn; consequently the development and introduction of the 16-in. Whitehead torpedo into the British Navy was watched by Japan with the closest interest. These new weapons led to the construction of special fast vessels to fire them from, and in 1877 the first British torpedo-boat was ordered.

She was defined as a small light-draught vessel, whose main armament is a torpedo and whose function was to attack and destroy larger vessels in harbour or the open sea. The main requisite in this type is speed; this allows a hostile ship to be approached at a rapid rate, to make fast journeys from a base where hostile ships are likely to be, and in daytime to flee from an enemy.

The tremendous powers of aggression possessed by torpedo-boats led to a large number of these craft being constructed in Europe.

To meet this menace the British Government replied with various types of torpedo craft, and ultimately produced the destroyer. This vessel is merely a torpedo-boat of superior speed, armament and endurance.

Most nations since that time have adopted the destroyer or first-class torpedo-boat, and have tended to abandon the smaller type.

Japan, recognising the great possibilities of the locomotive torpedo, was not long in following the Western lead, for we find her

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possessing, at the time of the outbreak of hostilities with Russia in 1904, nineteen destroyers and fifty-eight first-class torpedo-boats and several second-class boats.

Many of these boats were built in sections in Europe and then put together in the Japanese yards. Admiral Togo, in deciding to strike the first blow with the locomotive torpedo, showed Europe that he was a great leader, by at once resorting to the most scientific weapon at his disposal for the purpose of attacking his country's enemies in their most vulnerable part, *i.e.* that portion of the Russian ships below the water-line. The whole of the war bristles with the performances of the Japanese torpedoists, which are briefly alluded to in subsequent chapters under their respective headings.

In the first attack on the Russian fleet at Port Arthur, on the night of February 6–7, 1904, it is now generally believed that only four or five Japanese destroyers actually went into action, and, assuming that they fired two torpedoes each, we find three ships were badly damaged at an expenditure of ten torpedoes at the outside; in other words, 30 per cent. of the torpedoes fired were hits.

Had the Japanese not wished to conceal their attack on the Russian battleships, they could easily have sunk some of the outlying cruisers, and possibly the percentage of hits would have been higher.

Writers in this country, in reviewing this and subsequent torpedo attacks, frequently assert that the torpedo is now a discredited weapon. Why? One might as well say the rifle is discredited because the percentage of hits in the South African war was a very small figure indeed.

In both the Spanish-American war and the Russo-Japanese war the authorities decided that, as their navies were small and the chances of European intervention great, no unnecessary risks were to be run. This is the chief reason why the Japanese did not make a better use of their great opportunities with the torpedo. In addition to some lack of supervision in the adjustment of their torpedoes, there are the inherent disadvantages of all operations undertaken by surface torpedo craft, which may be briefly stated as:—

1. Bow wave thrown up when travelling at high rates of speed can be easily detected and shown up in the rays of a searchlight.
2. Flames or sparks coming up the funnel.
3. Noise of engines on a calm night.

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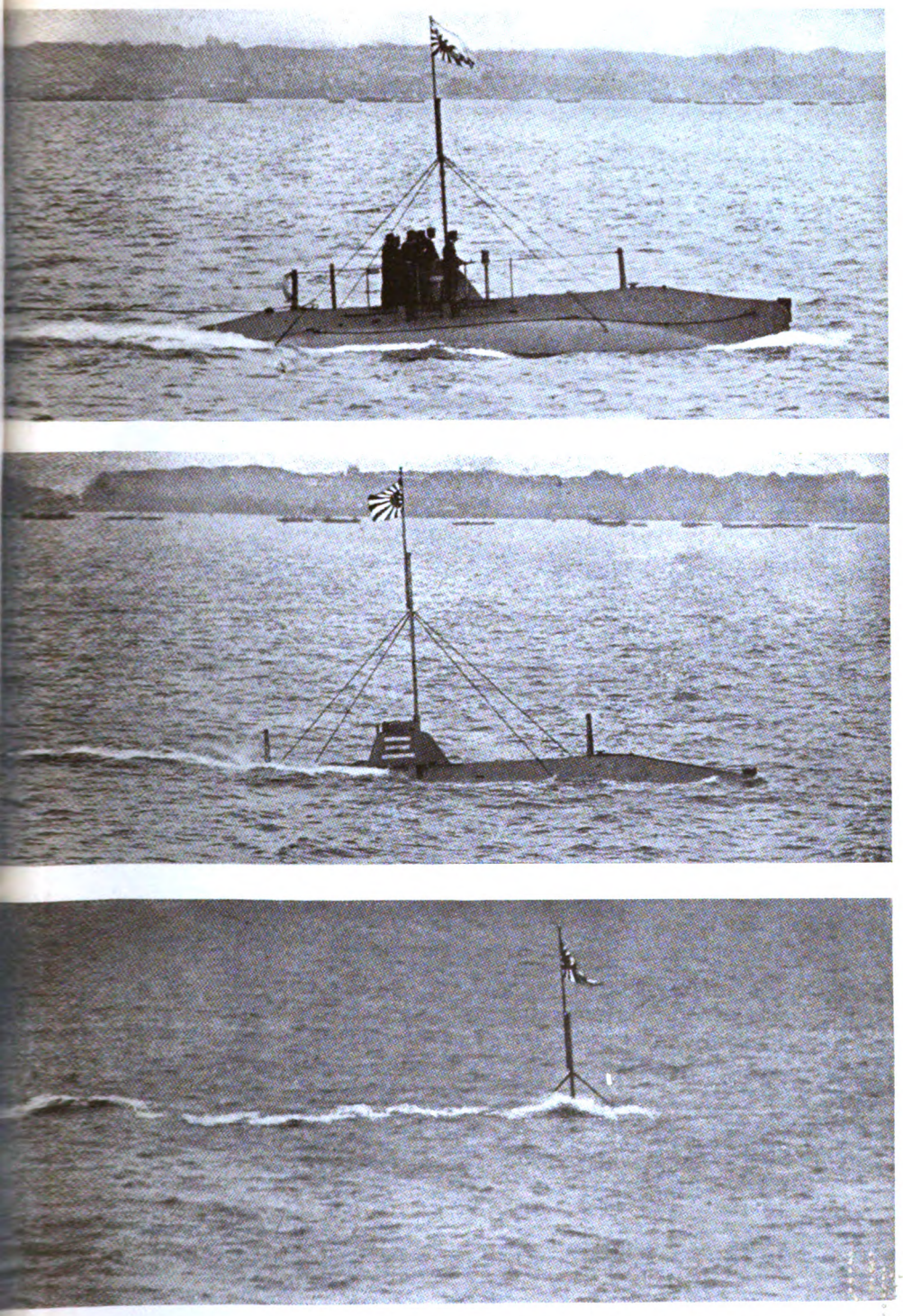

PLATE 67.—*A JAPANESE SUBMARINE RUNNING ON SURFACE, AWASH AND SUBMERGED.*

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4. The crew and their weapons are quite exposed to gun-fire.

In all night attacks by torpedo vessels invisibility and noiselessness are of the utmost importance; careful stoking is necessary, as the mere sign of a spark up the funnel puts the watching ship on the alert.

There can be no doubt that the efficiency of the surface torpedo-boat craft is, even under the most favourable conditions, limited by these disadvantages, and this type offers at best only a crude means for taking the torpedo within range of a hostile ship.

Recognising this, the Japanese during the war* acquired five submarine boats of the "Holland" design; their forms are shown on Plates 66 and 67.

These were all built in sections at the Fore River works, Quincy Point, Mass., U.S.A., and approximately on the same lines as the "Fulton." This shipbuilding yard is situated twelve miles from Boston, and the secrecy of their construction was well kept. The hulls were built in three sections and shipped on special railway trucks to Jersey City and then to Seattle, from which port they were taken to Yokohama, arriving there during December 1904.

The supervision of connecting the sections was under an English engineer who had worked with the Holland Company for many years at Nixon's yard, Elizabethport, N.Y.

The chief feature in the Japanese designs is that the hulls are made stronger than the ordinary Hollands. The best steel was used in their construction, reinforced amidships by a 10 ft. strip of tobin bronze plate $\frac{8}{16}$ in. in thickness. The hulls are designed to withstand the pressure at a depth of 125 ft. without distortion.

The dimensions are:

Length . .	58 ft. 9 in.
Maximum depth	11 „ 9 „
Surface speed .	9 knots.
Submerged .	8 „

The hulls have bilge keels fitted 9 in. wide, extending for a length of 24 ft. 6 in. and made of $\frac{6}{16}$-in. steel plate. Unfortunately these boats could not be got ready in time to take part in the battle of the Sea of Japan, and even if they had been, it is very unlikely that the crews in so short a time could have been efficiently trained in this special work.

* Russo-Japanese war, 1904-5.

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All the five boats have now been launched, and we are not surprised to learn that they carried out successful evolutions before the Emperor at the Naval Review held towards the end of 1905.

The Japanese Admiralty are about to increase their submarine flotilla, as they firmly believe that these weapons are most suitable for the protection of their important naval and commercial ports. Rumours are persistent that a shipbuilding firm in the North of England is building submarines in sections for Japan, and it is believed they are to be a combination of the latest "Holland" submarine and Mr. Lake's type. If these boats embody the good points in each design they will be formidable weapons.

The general policy of the naval authorities in Japan is to provide the very latest weapons of war, and there can be little doubt that the management of submarines demands precisely the qualities in which the Japanese excel, namely, strict obedience to orders, absolute fearlessness, and true patriotism. This combination never shrinks from self-sacrifice should occasion demand it.

Submarines of Portugal.

An officer of the Portuguese Navy has been interested in submarine navigation for close on twenty years. Lieutenant Fontes carried out his first experiments with a small boat in 1888-9.

The form of this submarine is shown in the diagram (Fig. 30), the midship portion being cylindrical with conical ends.

Two large reservoirs were fitted, one at each end of the cylindrical portion of the boat; these were used for taking in water ballast for submerging. Electric accumulators furnished the energy to motor-pumps for ejecting the water from the reservoirs when required. In experiments carried out in the basin of the arsenal at Lisbon, this method of submergence was proved to be quite satisfactory, and also a periscope for reflecting objects on the surface to those in the interior of the boat was found to be useful.

These experiments led to the construction of a larger boat, which was launched in 1892, of these dimensions:

Length	72 ft.
Maximum diameter. .	11·5 „
Surface displacement .	100 tons.
Armament . . .	2 torpedo-tubes.

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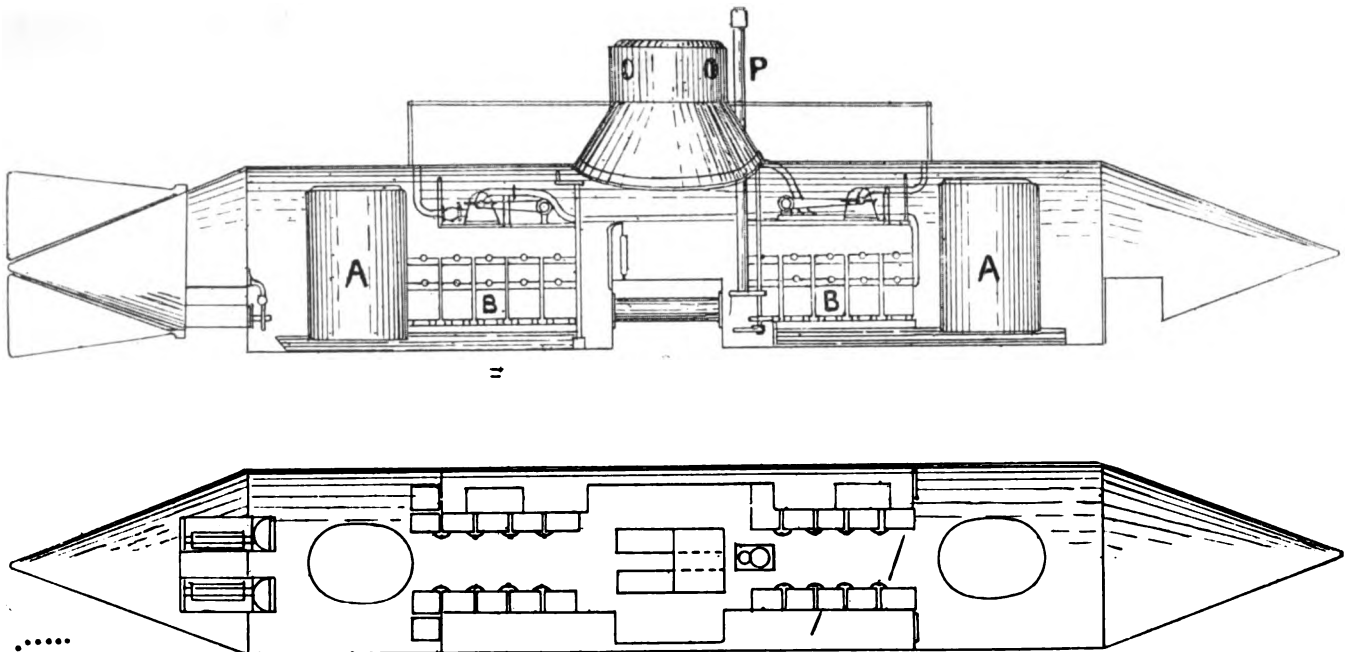

FIG. 30.—"*FONTES*" *SUBMARINE BOAT.*

A.—Water Ballast Reservoirs. *B.*—Electric Accumulators. *P.*—Periscope.

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The motive power for surface and submerged work is provided by electric accumulators, and it is understood that a speed of 6 knots was obtained on the surface with this submarine, but it is presumed the trials were not quite satisfactory, as the design has not yet been repeated.

The Portuguese naval authorities are carefully watching the progress other nations are making in the provision of these weapons for defensive purposes, and no doubt a small submarine programme for coast defence will be the outcome of their investigations.

Submarines of Sweden.

In a former chapter dealing with the Nordenfelts the reader may perhaps recall that in 1885 the first submarine of that name was built at Stockholm, and subsequently underwent trials at Landskrona. Her constructor, Herr Enroth, modified the "Nordenfelt" design and built a boat which he called the "Enroth," having a

Length of . .	25 metres.
Maximum beam .	4 „
Depth . . .	3½ „
Surface displacement	100 tons.
Submerged „	120 „

Mr. Nordenfelt's system for submerged and surface propulsion was copied. No particulars of the trials of this boat are forthcoming, so presumably she was not any great success.

Lately the Swedish Government have not been altogether backward in recognising that the modern submarine is an important weapon for the purposes of coast defence, as a boat named "Hajen" has been recently built in the Stockholm dockyard on the lines of a Holland (Plate 68). The dimensions are:

Length . .	65·7 ft.
Maximum diameter	9 ft. 9 in.
Displacement .	105 tons on surface
„ . .	120 „ submerged.

For surface running a four-cylinder vertical petrol engine of 180 H.P. is provided; this was constructed in Messrs. S. V. Ivensson's Automobile factory.

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Electric batteries are provided for submerged work. The armament consists of a torpedo tube placed in the extreme bow, with one 18-in. locomotive torpedo carried in the tube, and provision made for carrying one spare torpedo stowed each side on top of the battery hatches.

A periscope is also fitted for conning purposes when submerged. In the preliminary trials the "Hajen" has had some considerable trouble with her petrol engine, but these difficulties will be overcome when the crew get more familiar with their work.

It is understood that four more submarines of this type are to be constructed.

Submarines of Holland.

The Dutch Admiralty has been watching with great interest the development of the submarine boat by her neighbours, and at last has been forced to the conclusion that these vessels are reaching a degree of perfection hardly imagined a few years ago.

A boat on the American "Holland" design was chosen to start experiments with, and is now * carrying out trials under the name of "Luctor et Emergo." † If these preliminary experiments turn out successful, it is anticipated that Holland will provide herself with an up-to-date submarine boat flotilla.

Submarines of Austria.

Austria is practically the last of the maritime nations to take up the submarine boat.

Whilst in the purely experimental stage, the Austrian Admiralty decided to wait before adding these vessels to their fleet.

Credits have been voted for the provision of two submarines of the "Holland" type,‡ and their construction is to be pushed forward as rapidly as possible.

Having briefly glanced at the progress made during the last few years in the development of the submarine boat by the most

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* 1907.

† I struggle and then come up.

‡ These boats are being built by Messrs. Vickers, Sons and Maxim, at Barrow-in-Furness, 1907.

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PLATE 68.—*SWEEDEN'S SUBMARINE "HAJEN" IN TOW.*

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important maritime nations, I should like to conclude this chapter by advancing one argument in favour of this type of war-vessel, and that is that these boats are a much better return to second-rate Powers for money expended than that obtained by the provision of second-class battleships and small cruisers.

The submarine boat, however old, if kept efficient and provided with the latest pattern locomotive torpedo, has always the means of inflicting a blow that will place a hostile ship in a precarious condition until she reaches port, even if nothing worse happens. On the contrary, small battleships and cruisers of doubtful fighting value can never face the mammoth war-vessels of the present day without certain destruction to themselves, whilst little harm can be done to their opponents.

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CHAPTER XVI.

STABILITY.

THE science of hydromechanics is divided into three parts, one of which, hydrostatics, deals with the equilibrium of fluids. The elementary principles were first enunciated by Archimedes in a work on the subject dated about 250 B.C. A few generalities in connection with submerged bodies are as follows:—

1. A substance or fluid of less specific gravity floats in one of greater.

2. The pressure at any point of a fluid at rest under gravity varies as its depth. Thus, the head of each foot of water produces a pressure of 0·433 lbs. to the square in. We learn from a series of experiments such as those undertaken by the "Challenger"* expedition that the pressure varies from 14·7 lbs. to the square inch on the surface to 28 lbs. at a depth of 32 ft., and so on in proportion to great depths; also the weight of a unit volume of water remains constant at any depth, as for practical purposes this fluid is incompressible.

3. The buoyancy of a floating body in water is the upward support given by the water.

4. The weight of water displaced is equal to the product of its volume into the weight of water per unit volume.

5. The amount of water displaced has a volume equal in weight to the weight of the floating body.

6. Reserve of buoyancy is the volume of water-tight compartments that are above the water plane when vessel is at rest.

7. The centre of gravity of any system involving weight is the point at which we may consider the whole system to be concentrated, and through which point the weight acts vertically downwards; this applies also to bodies immersed partially or wholly in a fluid.

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* Exploring voyage of H.M.S. "Challenger," 1873.

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8. The centre of buoyancy of any vessel floating freely at rest, either on the surface or wholly submersed, is the centre of gravity of the displaced fluid.

Any type of submarine boat must essentially be designed to have sufficient buoyancy to enable the crew to pass freely in or out, also to allow indispensable stores being carried.

Mr. Holland laid down that about 8 per cent. of the total displacement should be out of water. This gave his first designs when lying on the surface about 18 inches of freeboard with two-thirds of their entire length submerged. In this condition these boats are subject to the same laws as any other vessel.

If all the water ballast and fuel tanks are empty, the weight of the submarine is a minimum; therefore the reserve of buoyancy is a maximum; consequently the reserve of buoyancy varies directly with the amount of water ballast or fuel in the tanks.

The actual stability conditions in a submarine boat are quite different from a vessel designed for surface running only. In a surface vessel the centre of gravity is generally above the centre of buoyancy, the equilibrium is stable for moderate inclinations, as the tendency of the mechanical couple is to right the vessel when inclined. In an under-water vessel the centre of gravity must be below the centre of buoyancy, and the latter in a submarine boat takes the place of the metacentre.

The most important point we learn from nature is to have a fixed centre of gravity. This has not been carefully considered by a large number of designers and has led to many failures. The chief cause of the movable centre of gravity is improperly filled ballast-tanks. If the boat is given an inclination by the rudders and the tanks are not quite full, the water piles up at one end and so alters the centre of gravity. Therefore all tanks for holding water ballast should be subdivided as much as possible and kept full or empty. This does not apply to small auxiliary or buoyancy tanks, as they only carry a few tons in the former and less in the latter, but to the large main ballast-tanks; also all weights consumed as fuel should be compensated for by an equivalent amount of water ballast.

In a condition of equilibrium, a body floating freely and at rest in still water, the weight acts downwards through the centre of gravity, and the buoyancy acts upwards through the centre of buoyancy.

If a vessel under these forces has no tendency to move, it must

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act in the same vertical line, that is, the centre of gravity and centre of buoyancy must be in the same vertical line.

There are thus two conditions which are satisfied in the case of a body floating in equilibrium:

1. The weight of the body exactly equals the weight of volume of water displaced.

2. The centre of gravity and centre of buoyancy must be in the same vertical line.

This equilibrium, however, may be either—

(*a*) Stable,

(*b*) Unstable,

(*c*) Neutral.

When applied to ships * these kinds of equilibrium are defined as follows:—

(*a*) Stable: if the vessel be slightly inclined from her position of rest, she would tend to return.

(*b*) Unstable: if slightly inclined from her position of rest, she tends to incline further.

(*c*) Neutral equilibrium: if inclined, she neither tends to return to nor to incline further from the position of rest.

Taking a submarine boat (Fig. 31, I, II, III), of circular cross-section at midship part (this is in many types the method of construction), and totally submerging her, any inclination to starboard or port, forward or aft, will not alter the under-water form. Under these conditions the upward force of the buoyancy must act through one point, which is the centre of buoyancy, B, and which, under these conditions, coincides with the metacentre. Taking G as the centre of gravity, which is always kept low in this type of vessel, suppose we incline the submarine through an angle θ. B remains a fixed point and also G.

The righting couple then becomes W × GZ; the stability is thus determined by the distance between B and G.

The righting arm at an inclination θ is BG × sin θ; this is a maximum when θ becomes 90°, as sin 90° = 1.

On increasing the inclination the righting arm vanishes when θ becomes 180°, as sin 180° = 0.

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* For further particulars of stability of surface ships see *Warships: a Text-book on Construction*, by E. L. Attwood, M.I.N.A.

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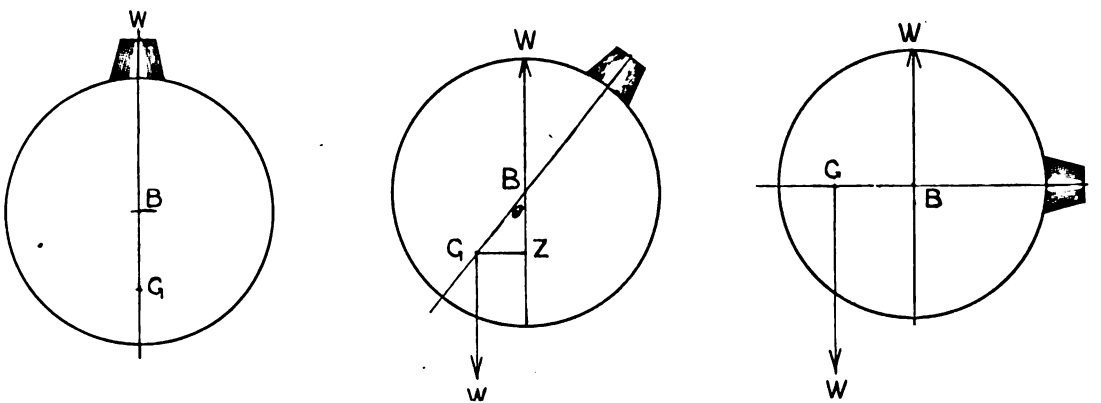

I. II. III.

FIG. 31.—*A SUBMARINE UNDER TRANSVERSE INCLINATIONS.*

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With the centre of buoyancy approximately fixed, it follows that G, the centre of gravity, must be brought as low as possible, that is, all weights should be placed low down so as to make BG a maximum.

The above shows how stable the submarine boat is under any transverse inclining force, as the couple exerts its greatest righting influence when the conning-tower is right over, as at Fig. 31, III.

Transverse stability is not so important in submarine design as longitudinal stability, provided the centre of gravity is below the centre of buoyancy.

For longitudinal stability the distance between centre of buoyancy and centre of gravity is the same as for transverse stability. The case is quite different from that of a surface vessel, where the longitudinal stability is far in excess of the transverse stability.

The longitudinal metacentric height, as in surface vessels, depends entirely upon the water-plane area. As water ballast is taken in, the boat sinks, and in the cigar-shaped boats the water-plane area diminishes, consequently the longitudinal metacentric height diminishes also. When the boat becomes entirely submerged, the longitudinal metacentre coincides with the centre of buoyancy, and the case becomes analogous to that of transverse stability. In the first British Hollands this was reduced to 11 inches and was a great feature of the design, as it enabled the boats to dive like ducks when using a comparatively small rudder angle. With such a small longitudinal metacentric height, it follows that these vessels are extremely sensitive to anything which may upset their fore and aft equilibrium, and changes in disposition of weight are more likely to take place in direction of length than breadth.

The following experiment with one of the United States submarines illustrates this sensitiveness. The boat was trimmed for diving in a horizontal position with 300 lbs. positive buoyancy and a metacentric height of 12 in. Two men weighing together 370 lbs. were moved to the extreme bow, close to the fore trimming tank bulkhead, whereupon the boat inclined by the head 2°. On moving the men right aft close to the stern gland bulkhead the trim was altered to 1½° by the stern.

Under normal conditions many submarines are designed to have a reserve of buoyancy of 8 to 10 per cent. of their total displacement.*

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* Submersibles have considerably more than this and are generally designed to have a reserve of buoyancy of 25 to 30 per cent. of their total displacement.

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Now to reduce this reserve buoyancy there are two ways. In the first method weight can be added by admitting water ballast into the tanks, then the boat begins to sink in the water, for her weight must be equal to the weight of volume of water displaced. This admission of water is continued until the boat has only her superstructure awash; she then has the reserve of buoyancy due to conning-tower alone—about 600 lbs. By taking in a little more water ballast this reserve of buoyancy is lessened and lessened until her weight exactly equals her volume multiplied by the weight of unit volume of water; she then is in a state of statical equilibrium. The slightest amount of weight added would make the boat sink, or weight ejected would cause her to rise, the quickness of descent or ascent varying with weight introduced or removed; that is, weight is greater or less than the upward buoyancy force, therefore motion must ensue.

From the very earliest boats of Drebell, De Son, etc., this simple law of hydrostatics was understood.

Theoretically a boat should remain at any depth in a fluid once the equilibrium of weight of boat being equal to weight of volume of fluid displaced has been established.

Many writers allude airily to the ease with which this balance can be obtained, but it has great difficulties, as most submarine workers know. Even when submerging in a dock alongside a wall, the writer has sometimes taken half an hour to obtain a perfect balance at a depth of 15 ft., and then only maintained it for a short time, the boat always having an inclination to rise or sink.

The following causes tend to make this perfect equipoise difficult.

1. Slight movements of crew.
2. Air-pockets in superstructure.
3. Tide.
4. Leaky kingston valves.
5. Leaky vent valves of ballast-tanks.
6. Leaks in air service, causing air bubbles to escape rapidly through hatches, joints, etc.

The valves may not always be ground in perfectly tight, consequently a little extra water may find its way into a tank not quite full, or sometimes an air-pocket exists in the superstructure or fair waters, and only becomes expelled on a slight inclination being given to the boat.

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When the release occurs, the air-pocket is replaced by water which is not buoyant. In some cases the air-pockets, on being released, have caused boats with a few hundred pounds of positive buoyancy to suddenly acquire negative buoyancy.

Once the positive buoyancy is lost, the submarine rapidly gains downward momentum. To check this, water ballast must be discharged to reach the surface or restore the balance.

Also, if through any cause a leak to a partly filled tank occurs, or through a collision water comes into the interior of the hull, and thereby adds weight, extra reserve buoyancy must be rapidly secured. For this purpose three systems are provided.

1. Ejecting water by admitting air under pressure into the tanks.

2. Pumping out water with a pump driven by electric motor. Very often a main and auxiliary motor pump are fitted for this purpose.

3. Emptying the tanks by means of hand pumps.

The air service is the simplest, safest and quickest method that can be provided for emptying the ballast-tanks, and it is not easily put out of action. To expel water from a tank, it is necessary to admit air at a pressure considerably in excess of the external fluid pressures. This is quite practicable up to depths of 50 feet; but at depths of 100 feet and over it is unsafe to admit the necessary pressure for fear of collapsing the tank. If through any mishap the boat should happen to be on the bottom in an excessive depth, then the electrical power pumps must be used. Pressure may be admitted to the tanks to assist the pumps. Should the power pumps fail, the hand pumps can be resorted to. These are very useful for keeping the tanks dry when the submarine is in harbour, and avoid waste of fuel in form of electricity * or air.

To obtain reserve buoyancy very hurriedly, some boats are provided with safety drop-keels or weights that can be slipped in moments of emergency. These safety weights or detachable keels are not in general use because submarine experts are divided in their opinion as to whether the advantage gained by being able to slip them in a fraction of a second, quite regardless of the depth of submergence, overrides the following disadvantages.

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* Also the life of an accumulator-cell depends on the number of complete cycles of charge and discharge, see Chapter XVIII.

Peter D. Meyerhoff 11/6/89

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1. The weights must not be made too large as, when once slipped, the boat ceases to be a submarine, and therefore loses fighting efficiency by being unable to seek under-water protection from hostile gun-fire.

2. The weights when dropped are usually lost.

3. The submarine has to be docked to replace the recovered weights, or, if lost, fit new ones.

4. As docking accommodation is not always available, the testing of weights sometimes cannot be carried out. Particularly might this happen if the boats were on service; consequently failures in emergency might occur.

The safety keels or weights have undoubtedly in some cases prevented mishaps, as in the Bonite-Suffren * incident; in others, as the "Lutin" accident, several of the safety weights were found in position after the submarine was raised; could they all have been slipped at the critical moment perhaps the disaster might have been prevented.

In the second method of reducing buoyancy of a boat, the displacement is altered, as was done in the "Nautilus" of Messrs. Ash and Campbell. In the diagram † (Fig. 32) the disposition of the pistons and cylinders for increasing or decreasing the volume of displacement is shown. When the operators required to submerge their boat, after first placing her in diving trim by the admission of water ballast, the pistons in the cylinders on each side were withdrawn. This gave the submarine less displacement and caused her to sink until the pistons were worked to make the weight of volume of water displaced equal to the weight of the boat.

To rise, the pistons were pushed out to give the boat a greater volume of displacement, and once more equilibrium was established. When the pistons were right out a certain proportion of the hull was out of water. As this method necessitates excrescences on the side, with additional machinery for working the pistons, it has been entirely abandoned in modern submarine construction.

Counting the two previous methods of destroying reserve buoyancy, we are in a position to enumerate the five systems of diving now usually recognised.

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* Page 99.

† For outline of hull showing the eight pistons see Chapter IX (Fig. 16).

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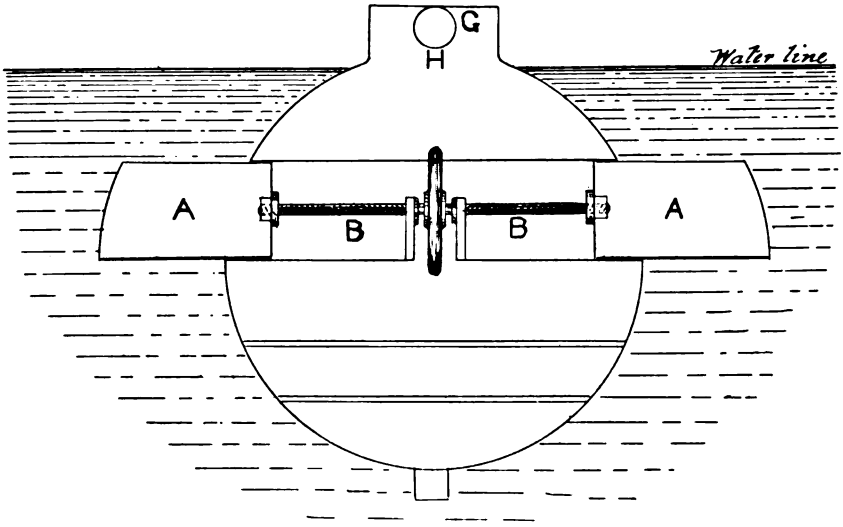

FIG. 32.—*TRANSVERSE SECTION OF "NAUTILUS" OF ASH AND CAMPBELL SHOWING PISTONS FOR INCREASING OR DECREASING VOLUME OF DISPLACEMENT.*

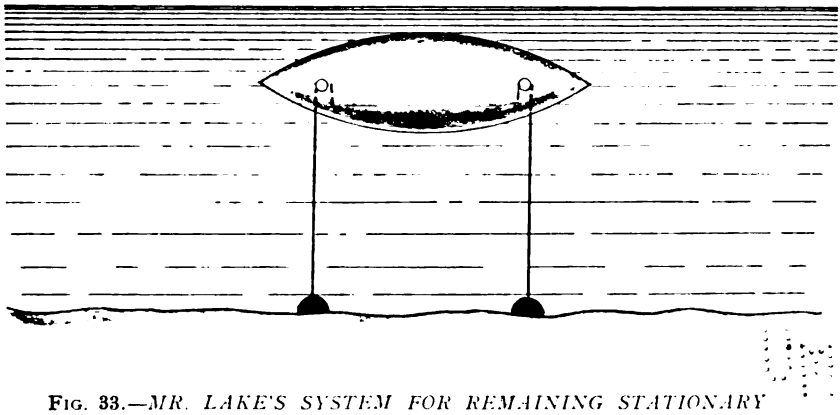

FIG. 33.—*MR. LAKE'S SYSTEM FOR REMAINING STATIONARY UNDER WATER.*

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1. Submergence by taking in water ballast until the weight of boat is made exactly equal to the volume of the boat multiplied by the weight of unit volume of water.

That is, all reserve of buoyancy is destroyed and a perfect equilibrium established when entirely submerged. This was one of the features in early submarines and latterly repeated in Goubet's boat.

2. Change of volume displaced, weight of boat remaining constant, as adopted in the submarine "Nautilus" of Ash and Campbell.*

3. With a small reserve of buoyancy vertical screws can be used to overcome the upward force and take the boat under water.

It is common knowledge that when the ordinary screw propeller is revolved at one end of a boat, motion is obtained either ahead or astern according to the direction of rotation. In a similar manner this motion can be obtained upward or downward in the vertical plane. The later submarines of Messrs. Garrett and Nordenfelt had vertical screws, one placed at each end of the boat, which were used for this purpose.

4. With a small reserve of buoyancy the boat can be caused to take an oblique dive by the use of horizontal rudders.

In this system motion is essential to enable the horizontal rudders to have sufficient power to take the submarine under the surface, and, when once under, to keep her on an even depth-line.

The "Holland" submarine requires a speed of 5 to 6 knots to keep effective control, with a reserve of buoyancy of some three hundred pounds.

5. With a small reserve of buoyancy the dive can be more effectively made when in motion by making use of symmetrically disposed hydro-planes. The French submarine "Narval" has six of these horizontal rudders, two forward, two amidships and two aft. The United States submarine "Protector" has four, two located on

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* If once the weight of a body floating in water becomes greater than its volume × the unit weight of water, then it will commence to sink and continue to do so to any depth; for water being almost incompressible, the unit weight of water is practically constant for all depths.

The body's downward motion may be arrested either by increasing its volume, weight remaining the same, or by decreasing its weight, the volume remaining the same.

From this it will be seen that the idea that there is a certain depth beyond which no wreck will sink is a popular fallacy.

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each side amidships and level with the superstructure deck. These hydro-planes are coupled together and controlled by means of an electric motor working rod-gearing.

As the boat moves forward the pressure of water acts upon the inclined hydro-planes; this forces her under the surface against the reserve of buoyancy, at a very small angle of inclination. The great advantage in such a system is that the boats can be constructed so as to be less sensitive to longitudinal alterations of weight.

In Mr. Lake's system of submergence for remaining stationary under water, all reserve of buoyancy is destroyed, then two anchor weights are dropped when the boat is somewhere near the required depth (Fig. 33). The boat tends to rise, but the weights on the bottom prevent this, and by an adjustment of the windlass she can be kept at any depth required. Under certain conditions this may be a most useful method of submergence for a boat lying off an entrance to a port on look-out duties, etc.

Of the five systems of diving, those boats that destroy all reserve buoyancy and depend upon establishing an equilibrium, on the equality of weight and displacement principle, may be termed, for want of a better name, the "statical diving type of submarine."

Whereas those that require motion on the boat before the dive is made can be referred to as the "dynamical diving type of submarine."

During the last few years boats designed on the principle of the dynamical dive have been most successful whether they use hydro-planes to assist the horizontal rudders for control in the vertical plane or not.

In pursuing the theoretical side of our subject we have to study a boat entirely submerged and moving ahead on an even keel with centre of buoyancy and centre of gravity in the same vertical line (Fig. 34).

With a boat having positive buoyancy, the forces acting are MA upwards, the excess of buoyancy over weight, and MN due to thrust of propellers. The resulting force is MO, and the boat will break surface along some line slightly below MO, say MP, there being greater resistance to upward motion than to forward, and the tendency is always to go in the direction of least resistance.

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FIG. 34.

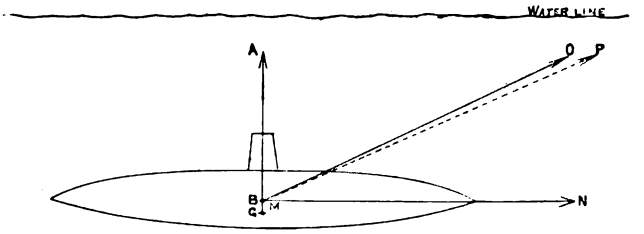


FIG. 35.

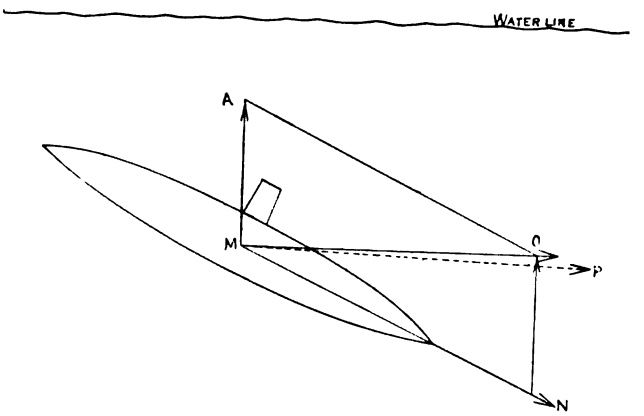


FIG. 36.

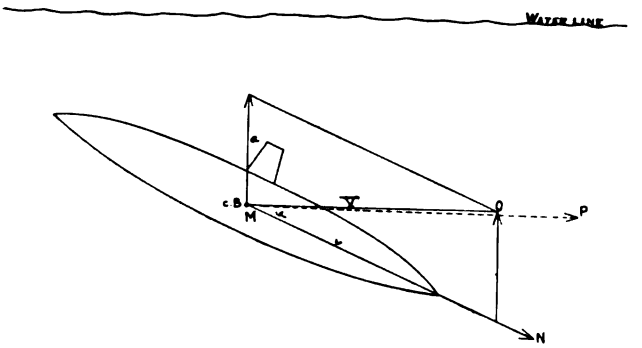
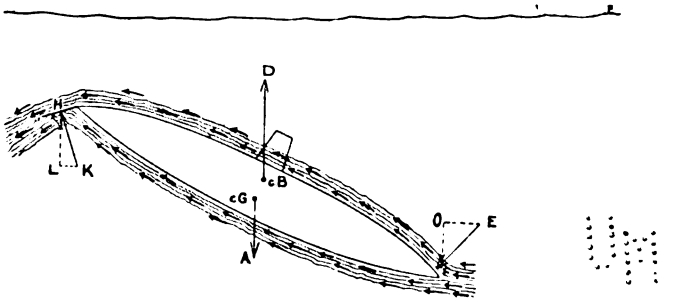


FIG. 37.



FIGURES SHEWING A SUBMARINE AT VARIOUS INCLINATIONS.

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To obtain running at a uniform depth we must consider :—

1. Forces governing actual course.
2. Forces tending to alter trim of boat.

Let boat be as shown in Fig. 35, and let there be no turning moment, then from previous argument boat's course will be MP, and required state is reached.

The only condition in which this can be possible is when the resultant is nearly horizontal.

If a = angle the axis of the boat makes with the horizontal plane (Fig. 36)—

$$\text{Then } a = v \,.\, \sin a$$

$$\frac{a}{v} = \sin a$$

$$V = v \,.\, \cos a$$

$$V = \sqrt{v^2 - a^2}$$

To obtain equilibrium of the system of forces which will keep the boat when in motion in a horizontal position, a mechanical force is introduced which, after once giving the boat the necessary inclination from the horizontal, can control her at the depth required (Fig. 37). Under the influence of this new force, given, for example, by a horizontal rudder, the bow of the boat is caused to dip under the surface of the water, and the fluid pressures set up on the hull cause certain forces to come into play.

In considering the turning moment under this new condition the forces acting are :

1. Weight of boat down through centre of gravity GA.
2. The buoyancy up through the centre of buoyancy BD.
3. Fluid pressures EF on the bows of the boat have a vertical component OF in the downward direction.
4. Fluid pressures KH set up on the rudder surface when in the down position have a vertical component LH in the upward direction.

Minor forces, such as the difference of pressure due to the bow of the boat being at a greater depth than the stern, or as unfilled ballast tanks allowing the water to surge, the crew making slight movements, etc., can, in a well-equipped and properly organised boat, be reduced to a minimum.

For equilibrium the moments of these forces about some point must balance. Since the forces are in equilibrium, this point is G, the centre of gravity, as this is of course the point about which the boat tends

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to turn; though if the boat was not in equilibrium she would turn about some other point, fresh troubles being introduced concerning water resistance. Now the only thing that can be measured here is BD into distance GB. GA does not come into "turning moments," provided the boat is in equilibrium, as G is the point about which boat tends to turn.

It is difficult to measure with accuracy the forces on rudder and the extra pressure assumed to be on nose, after deducting or adding various eddy effects all over the boat. Such calculations are either obtained by tank experiments, comparison with previous types of boat, or worked out from the drawings.

Following these considerations, we are able to state that a boat with reserve buoyancy, and only provided with horizontal diving rudders aft, must be capable of having its axis thrown at an angle to the horizontal to prevent the upward buoyancy force making the boat come to the surface.

Now Mr. Nordenfelt, in trying to keep his boat horizontal, and by using down-haul screws to overcome the buoyancy, found how exceedingly difficult it was to keep the boat under proper control, owing to the forces he introduced with the down-haul screws being unmeasurable. Theoretically the down-haul screws should be a perfect method of submergence, but practically the exact regulation of the screws is exceedingly difficult, and the disturbances on the external hull of the boat due to the revolution of these propellers quite upset the normal forces acting on the boat. A glance at the disturbed water in the wake of a screw-propelled ship shows innumerable eddies, of which many, in the case of vertical screws, would act adversely on the control of the submarine. These undefined forces, coupled with the free surfaces of water in the storage tanks, quite condemned Mr. Nordenfelt's system of submergence from a theoretical point of view.

We pass to the method employed by Mr. Holland in obtaining the oblique dive. This inventor's first submarine was based precisely on the lines of the Whitehead torpedo. The horizontal or diving rudders were placed right aft near the position of the vertical or ordinary gyroscope steering rudders, as seen in that weapon; that is, Mr. Holland and the great French engineers have improved on Mr. Nordenfelt's designs by replacing systems of unknown forces acting on the boat by forces that can be calculated approximately

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PLATE 69.—*MANOMETER AND INCLINOMETER.*

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from tank experiments and allowed for, as the following will show.

In actual diving with a submarine boat it is found that the forces acting downwards tend to be greater than those acting upwards. Consequently this tendency to make an excessive dive has to be checked by the helmsman on the diving-wheel at once reversing the horizontal rudders to the up position. Constant vigilance is then necessary to keep the boat at an even depth-line; to do this a manometer is provided for recording the pressures at depths up to 150 feet. This manometer is in direct communication with the sea. When the submarine lies on the surface of the water the manometer indicates the pressure due to the height of water from centre of gauge to the surface. The readings show pressures in pounds, with the depths in feet corresponding to those pressures. To keep a boat on an even depth-line, the indicator of the manometer is kept pointed at the depth ordered. The boat has to be as near the horizontal as possible for keeping a truer depth-line, therefore a bubble in a curved tube is placed on the lower portion of the manometer, as shown in Plate 69, and acts as an inclinometer for showing the diving-wheel helmsman the inclination of the boat from the horizontal.

Now to overcome the undue tendency to dive, chiefly caused by the downward force acting on the upper part of the bow portion of the hull overcoming the upward force acting on the rudder surface, when the horizontal rudders are given down-helm for diving and the buoyancy force acting upwards, French designers fitted in the "Narval" side rudders or hydro-planes.* These were first placed in the bow to introduce an upward force and thereby counteract the tendency to dive. By fitting these hydro-planes the horizontal rudders are relieved of a large proportion of their work, and consequently a truer depth-line can be kept. In actual practice, if 5° to 7° down-helm be given on the hydro-planes, with a similar amount of up-helm on the horizontal rudders, many modern submarines would take their depth almost horizontally, and with small helm can be kept on a very even depth-line. The form of the hull largely governs the most effective position of the hydro-planes; usually two are placed forward and two aft. The disadvantage in providing these

* See Plate 70a, hydro-planes and horizontal rudders of French submarine "Farfadet."

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side rudders is that they slightly cut down submerged speed, are easily damaged in taking the boats alongside securing jetties, etc., and may, if touched, tear the skin-plating, as they have to be made strong.

When the boat running submerged is suddenly stopped, the forces set up by the fluid pressures on the bow, hydro-planes, and horizontal rudders disappear. The boat then being lighter than the weight of volume of water displaced is forced by the reserve buoyancy to return to the surface.

The original intention to give as few technicalities as possible has, I fear, been slightly overstepped in this chapter, therefore the equations of equilibrium will not be pursued any further. These are simply a matter of mathematics by which the figures obtained from model experiments can be verified and used to form data for new designs. The drawings furnish the rudder surfaces, the speed is known. The resistance is in proportion to the square of the speed and varies according to how the surface friction of the boat is dependable on its inclination with the horizontal. Leaving these theoretical considerations, the reader may perhaps be more interested in the various phases for testing a submarine boat before deep-sea work.

On casting off from the buoy (shown in Plate 70), the submarine is taken into deep water in the dock, or, if working in a harbour, where the sea is fairly smooth with plenty of water underneath. The crew on deck disappear one by one down the conning-tower, the last to enter and close the hatch from the interior is the captain.

All openings in the hull, as ventilators, torpedo hatches, etc., are reported closed. The vents are then opened and also the kingstons, for admitting water into the main and auxiliary ballast-tanks. As water is taken in, the boat gradually loses buoyancy until the external water is swirling about over the superstructure deck plates.

All kingstons and vents are closed and only cracked again to admit a little more water ballast, should the captain require a further decrease of buoyancy. To allow of a boat being forced under water the reserve of buoyancy in the "Holland" design is reduced to some 300 lbs., in the "A" class to about 600 lbs., and in later types to half a ton. In this condition the boat is known as being "trimmed for diving," as shown in Plate 70 at (*a*).

Headway is then obtained by starting the electric motor for

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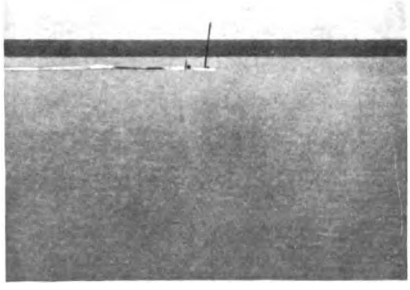
PLATE 70.—*A BRITISH HOLLAND SHOWING THE OBLIQUE DIVE.*

"IN SURFACE TRIM."

(a) *"TRIMMED FOR DIVING."*

"TAIL RISING OUT OF WATER."



"TAKING UP DEPTH."

RUNNING SUBMERGED.
Boat is to look out for Torpedo when discharged.

"RISE."

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driving the propeller. When sufficient speed has been got on the boat the captain gives the order to "dive," the coxswain on the horizontal diving rudders at once places them to about 8° down; this causes the bow to dip under the surface of the water, at the same time the stern goes up, and thus the oblique dive is made, the boat being taken to the depth required and kept there by working the diving rudders so that the pointer of the manometer indicates the depth ordered.

The accuracy of the depth-line naturally depends on the vigilance and skill of the coxswain. A good man in a finely trimmed boat, that is, one with not too much reserve buoyancy, would use from 2° to 3° dive to 1° rise on the horizontal rudders. The captain, with ordinary steering-wheel in hand, controls the direction of the boat by the aid of a compass or periscope, as preferred.

In dock-running at Barrow, unless the boat was accurately steered down the deep gut, the bottom would occasionally be touched; this did little harm beyond causing the periscope to vibrate, which made vision somewhat difficult. More than once in the Irish Sea the bottom was found in passing the first boats through their trials.

When this happens the bump is usually very light and may be compared to a balloon touching the earth gently and bouncing up again. With the submarine, the tendency is to rise to the surface, as in these cases the boats only had slight, if any, negative buoyancy through a little too much ballast having been taken in, etc.; a succession of bumps occurring would force the captain to take his boat to the surface to ascertain the cause.

In the deep-sea trials of "No. 4" submarine, during rough weather, the experiment was made of taking in water ballast when running, to lessen the inclination; this was done owing to the difficulty experienced in trimming the boat when the seas were breaking over the deck and the swell causing her to pump. On cracking a valve, water was taken in and the inclination lessened, until sufficient reserve buoyancy was destroyed to allow of a uniform depth-line being kept. This is not risky if done with care, and is very efficacious in bad weather.

In motion under water the control in the vertical and horizontal plane has been brought to the highest efficiency in the Whitehead torpedo. From actual experiment it is found that the effect of the pendulum weight and hydrostatic valve combination controls the

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depth-line to within a few inches of that adjusted for, during a run of several thousand yards. In the horizontal plane the gyroscope apparatus automatically directs the torpedo with great accuracy. Automatic appliances for controlling the vertical and horizontal rudders of submarines have now generally been discarded, as it is found that well-trained coxswains can keep modern boats at a very fair depth-line for long periods.

The control in the vertical plane is precisely similar to the ordinary steering of a boat when floating on the surface. All the reader is asked to consider is that, if he sat in the stern of the boat and worked a tiller attached to the horizontal rudders up and down, one way would make the boat rise to the surface and the opposite way make her dive instead of going to starboard or port as in surface steering.

The actual rise and dive is under perfect control in all modern submarines, provided the boat is in motion; should the submarine stop she will instantly rise to the surface by virtue of her reserve buoyancy. If hard up-helm is given when in motion the boat reaches the surface with greater rapidity.

There is one point to remember in steering under water, that is, the action of the ordinary steering rudder on the depth-line. If the boat is running at an even depth-line of 20 ft. below the surface and suddenly hard a-starboard helm is given, she naturally heels over like a surface boat, the vertical rudders then have a horizontal component and the boat dives unless checked; similarly, if the helm is put hard a-port the boat rises to the surface, therefore control in the case of altering course must be watched very carefully to forestall the slightest tendency to rise or dive unduly. The turning circle of the "Holland" submarine is about 130 yds.

Also, should the conditions of equilibrium be upset by discharging a torpedo, the horizontal rudders are used to prevent the boat breaking surface; a caution to the coxswain before firing is all that is necessary. If at any time it is noticed that the boat is taking less diving-rudder helm to keep her at an even depth-line than when first commencing the submerged run, some change in the conditions of equilibrium must be occurring, due probably to water leaking in by an imperfectly closed kingston valve.

To determine the effect on the diving-rudder angle of a "Holland" boat, one of the crew, weighing about 150 lbs. was moved from right

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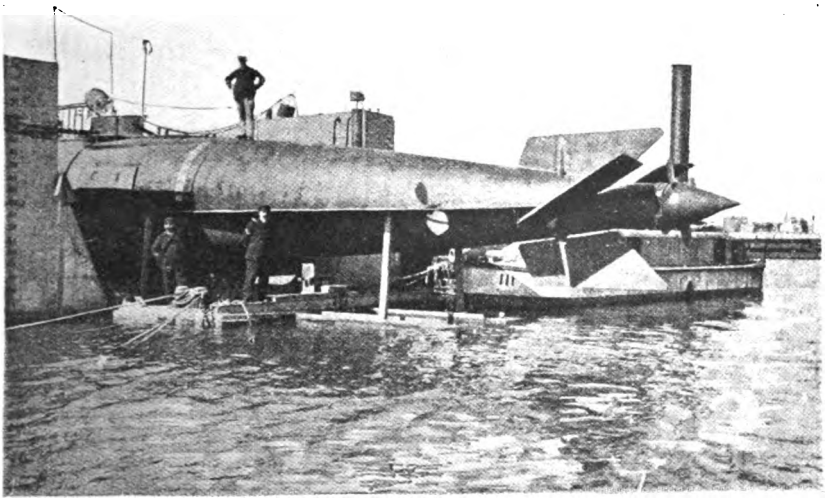

VERTICAL AND HORIZONTAL RUDDERS OF FRENCH SUBMARINE "FARFADET."

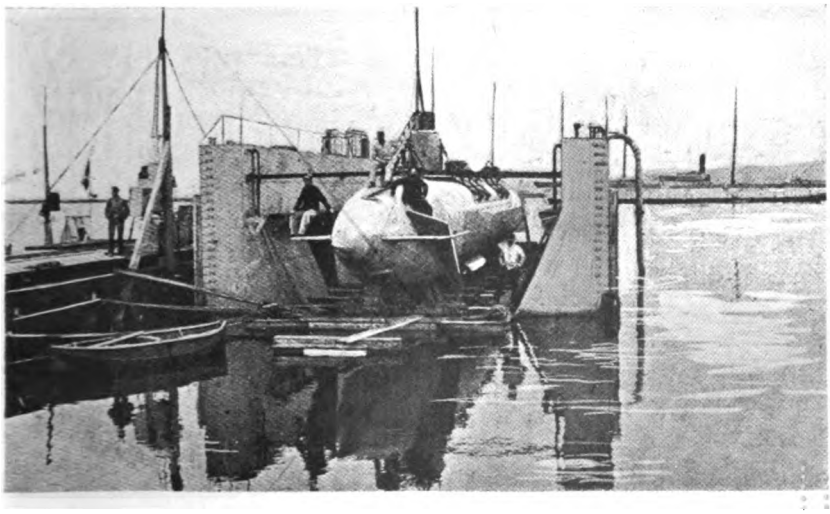

PLATE 70 *(a).—HYDRO-PLANES OF "FARFADET."*

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aft to the extreme forward position; this change of movable ballast caused an alteration of 1° to 1½° in the angle of diving rudder. The boat, before the man was moved, took from 2° rise to 5½° dive to keep on an even depth-line, and afterwards about 3° rise to 4° dive, plainly showing that when submerged the crew must remain in the near vicinity of their station, a small amount of movement only being permissible. As a rule, in practical work the crew move very little from their respective posts.

Every indication shows that submerged displacement will increase rapidly in the near future, consequently very high speeds under water are not desirable. The manipulation of seven to eight hundred tons below the surface at anything above a medium speed might land the boat in excessive depths before a rise to the surface could be brought about. A speed of 12 knots under water is equivalent to about 20 ft. per sec.; in a very few seconds the boat would reach 100 ft. If this speed were increased the diving-rudder surfaces would have to be considerably reduced to prevent large depths being reached in too short a time.

The power of the diving rudders was forcibly illustrated in "No. 1" submarine during one of her maiden trips, as the following episode will show.

When running on the surface down the Barrow Dock the order was given to increase the speed, and speed up the motors for taking the time on a measured course. The boat suddenly dipped her nose right under the surface as she felt the increased power, causing the water to come up to the conning-tower with the tail-half out of water. To the inexperienced it looked as if "No. 1" was going to the bottom of the dock nose first. The chief draughtsman of Messrs. Vickers, Sons and Maxim, standing on the fore-end of the boat busily engaged in looking for the shore marks, so as to take time over a measured distance for calculating the speed, became somewhat alarmed, and shouted, "For God's sake, man, stop her! Look at my new 'breeks'!" —the water then being up to his knees, with the deck rapidly inclining downwards and away from his foothold. The captain * of the boat was not in the least perturbed, and remarked, "She can't possibly sink"; then ordered 2° up-helm on the diving rudders. The boat felt this at once, and a little more was added, which brought her more out of

* Lieutenant A——— F———.

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the water. After this, care was always taken to keep a little up-helm on the diving rudders when speeding-up and trimmed low.

In the case of the serious accident to "A 8" submarine when manœuvring between Penlee Point and the western end of Plymouth breakwater, the evidence plainly showed that the captain of the boat gave over and over again the order for more "up-helm" to be put on the diving rudders. Without in any way attributing blame, it is just possible the coxswain on the diving rudder, finding the boat was not answering the helm that was being put on, worked the wheel hard down with the intention of bringing it hard up again to see all was clear; this is frequently done to test an ordinary steering-wheel.

The evidence showed that the boat was gradually settling down by the bow through water entering at a leaky rivet into one of the tanks at the fore-end, and suddenly became plunged into an uncontrollable submergence when going at a speed of 10 knots. As the nose dipped the bow pull became stronger and stronger, forcing the boat under the surface with the conning-tower hatch open. A large quantity of water thus went down the opening, destroying all buoyancy and flooding the electric battery tanks. As the boat lost forward motion the incumbent water closed the conning-tower hatch, and she finally came to rest in 8 fathoms of water. The battery, being flooded, probably evolved chlorine gas, and as the water reached the gasolene engine no doubt traces of free gasolene floated on the surface; this would rapidly vaporise and form an explosive mixture.

A short circuit, causing a spark, might then account for the explosions heard some time after the boat was on the bottom. The means taken to raise "A 8" were briefly as follows. Over the submarine two large mooring lighters were anchored and four wire hawsers passed under the boat, the ends were then taken over baulks of timber to steam winches in the lighters. The strain was very severe as the weight was taken, and ended by damaging one of the lighters. After several efforts it was soon apparent that these arrangements would not lift over 200 tons, therefore compressed air was used to force some of the water out, to lighten the dead-weight, and subsequently the boat was successfully raised.

After this accident the design of these spindle-shaped hulls was very much discussed in foreign papers, some authorities even going so far as to say this form of hull is unsafe. This is quite true if the principles involved are only partially understood, but if the boat is

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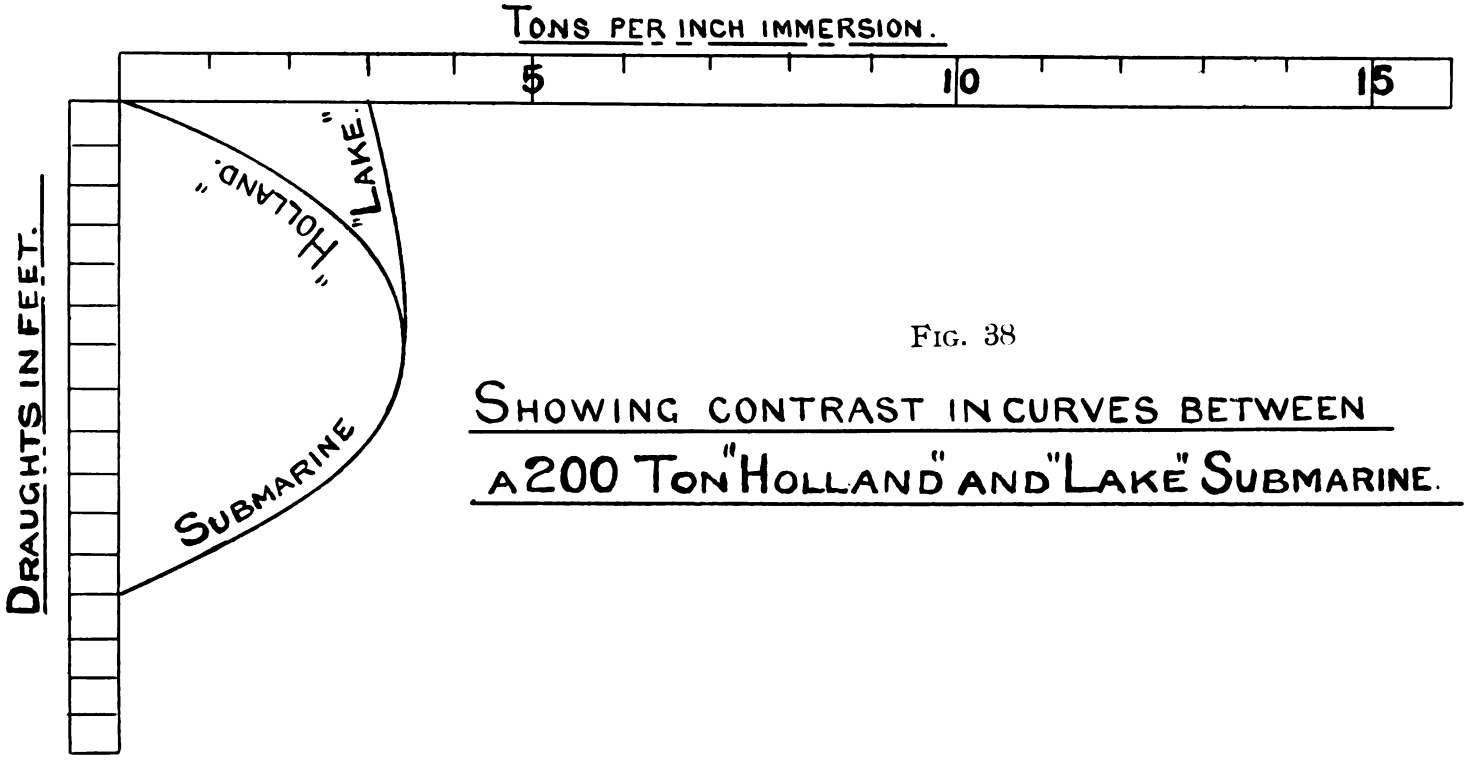

FIG. 38

SHOWING CONTRAST IN CURVES BETWEEN A 200 TON "HOLLAND" AND "LAKE" SUBMARINE.

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in capable hands she is as safe as any other type. From a diving point of view the system of the oblique dive with an unstable longitudinal trim leaves nothing to be desired; the boats go under water with the greatest ease. The contention that if the stern comes out of the water in the "Holland" design of boats all control is lost, as the rudders are right aft, has some force, and therefore a hydro-plane system of submergence contains much to recommend it.

The form of the hull in the "Lake" design* has always appealed to the writer, because very rapid changes in the water-plane area are avoided. If a tons-per-inch immersion diagram is made of the "Holland" and "Lake" design, the curves would be shown as in Fig. 38. Consequently, in the last stages of trimming for diving, great care is necessary in the "Holland" design.

The forms of the hulls vary largely. In the "Holland" and French submarines the water masses on the fore-part of the boat considerably when going at full speed, it then falls off short of the superstructure, forming a deep hollow with the crest near the conning-tower.

In the "Lake" design and French submersibles the mass of water on the bow is prevented by the provision of a built-up water-tight superstructure. This in every way makes the boat better for surface work, but it is detrimental to under-water speed. The spindle-shaped hull with little or no superstructure is undoubtedly the best for submerged work, as it more nearly approaches the lines of Nature's submarines, and has been adopted to overcome resistance as much as possible. For the size of the boat the skin friction is reduced to a minimum. The only drawback to this form is the poor longitudinal stability. The maximum diameter is in the centre, and the diameter of the cross sections towards the bow and stern taper away gradually.

On Plate 71 are shown the forms of the "Krupp-Germania," 1905, and "Lake," 1906, designs for comparison of the under-water lines with our "B" type, as depicted upon the cover, and the United States submarine "Cuttlefish" (Plate 109).

When a submarine boat is trimmed for diving the water-plane area is the area of the conning-tower only at the water level; this is naturally very small.

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* See Fig. 26a and Plate 44 for form of Lake submarines.

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According to Sir William White,* the longitudinal stability varies directly as the product of the breadth at the water-line by the cube of the length, and inversely as the volume of displacement. It follows therefore that as the draught is increased, since both breadth and length at the water-line are diminished rapidly in submarines, there must be a considerable diminution in longitudinal stability.

To borrow the ex-Chief Constructor's figures, in the ordinary service condition of surface trim, "with a reserve buoyancy of 13 tons (excluding conning-tower), the longitudinal stability may be expressed by the number 100. With a reserve of buoyancy of 6 tons the longitudinal stability falls to 73; with 3½ tons reserve it becomes 27; and in the diving condition, with 800 lbs. reserve, it is less than 7. These are striking results. It will be noted that whereas the surrender of 7 tons in the reserve of buoyancy is accompanied by a reduction of about 30 per cent. of the longitudinal stability existing in the surface condition, a further surrender of only 2½ tons involves a reduction amounting to 73 per cent. of the original value; while the final preparation for diving, with an additional surrender of rather more than 3 tons of buoyancy, increases the loss of stability to 93 per cent. If 1 ton is moved through 3 ft. longitudinally in the diving condition, the trim is altered one degree, the stern being raised or depressed relatively to the bow by about 2 ft., whereas in the surface condition the corresponding change would only be one-fifteenth that amount. The absolute necessity for assigning to every man a station at which he must remain, and for avoiding changes in the longitudinal positions of weights, when a submarine is being prepared for diving, will be understood from these figures, and needs no further explanation."

Mr. Whitney, of the Lake Boat Company, in his many able contributions concerning under-water boats, also strongly advocates a built-up superstructure for this reason. In spindle-shaped hull boats every gallon taken in reduces the water-plane area, and when near the "diving trim" a very little water ballast makes the boat lose buoyancy in that trim, whereas in the built-up superstructure it takes just as much water ballast to submerge the last two inches

* *Times* "Engineering Supplement." Sir W. White on Submarines, August 30, 1905.

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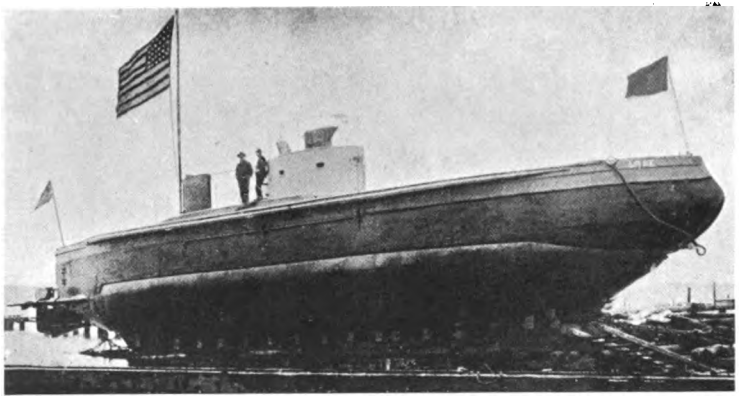

AMERICAN "LAKE SUBMARINE" LAUNCHED AT NEWPORT NEWS, U.S.A., FEBRUARY, 1906.

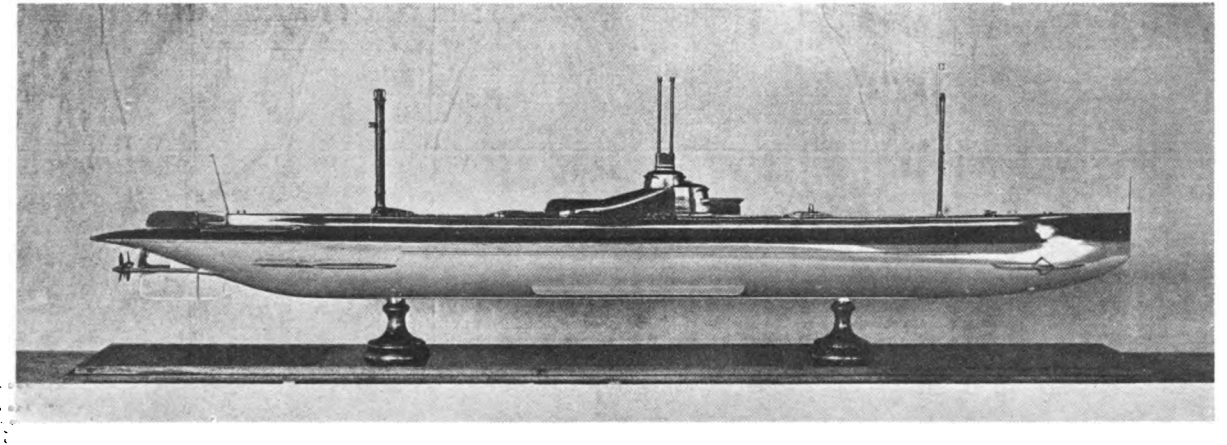

PLATE 71.—"*KRUPP-GERMANIA SUBMARINE,*" *LAUNCHED AT KIEL, AUGUST,* 1905.

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as it did the previous two, etc. The boat also has more longitudinal stability in this design, which should prevent an inexperienced operator from ever getting one of the "Lake" type into an uncontrollable submergence.

Safety arrangements in submarines are what tax the ingenuity of constructors most. In the first place, the boat is designed not to sink unless due to some untoward occurrence. Security is obtained by always keeping a reserve of buoyancy; this, however, is not proof against damage by collision, or any mishap to the conning-tower hatch, fuel explosions, etc.

Safety weights are useful, as by a turn of a handle many tons of buoyancy can be instantly obtained; and it may be repeated that in the Lake boat "Protector" a drop keel is fitted in two pieces, the combined weight being 10,000 lbs.; each section is 17 in. by 17 in. by 7 ft. 2 in.; one end of each is curved to allow clearance in dropping. These are hung by T-headed butts to a shaft which can be turned from the inside. A quarter of a turn will slip the drop keel.

It is practically impossible to render these boats entirely immune from danger any more than surface craft are. A very able paper was read by Captain Bacon on this subject before the Institute of Naval Architects.* He commented on all the likely accidents, most of which have been referred to in the different chapters of this book, and showed a chart of the Channel, indicating in what places the submarine can be manœuvred without any chance of going to excessive depths. The area inside 150 ft. is very limited, both on the French coast and ours, and, if kept to, would restrict the use of these weapons considerably. Safety lies and lies only in the constant care and attention to minute details by the officers in command of these boats, and being in this duty ably supported by their crews.

When in doubt or placed in some hitherto untried position, there is this golden rule to remember:

"Trust your boat. She is right."

The chances are you or your crew have overlooked something that has brought about this new condition. By following implicitly the

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* July 20, 1905.

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instructions, coupled with a judicious use of the appliances in the boat, most difficulties * should be overcome.

This does not apply to the loss of "A 1," as accidents by collision may happen to surface boats with equally disastrous results.

Experiments are now being carried out with a view to establish telephonic communication from a sunken submarine to the surface by means of a buoy capable of floating a telephone wire. In non-tidal waters this can easily be arranged, but where a tide of several knots may be experienced, difficulties present themselves in giving the buoy sufficient buoyancy to support a long length of wire. The position found most suitable is just behind the conning-tower, with the buoy placed in a cylindrical case, open at the top, and at the bottom special arrangements for releasing from the interior of the submarine; also special mooring lighters are now provided at all our submarine bases, with heavy rollers and powerful lifting tackles, for the purpose of raising a submarine should one from any cause be disabled and unable to reach the surface.

A valuable suggestion was put forward at the recent meeting of the Institute of Naval Architects† by Mr. Stephen Terney, who has for many years been intimately associated with submarine designs, and therefore I give his proposals fully as they merit close study. Mr. Terney says:

"My system consists in providing recesses built into the superstructure of the submarine or into the upper part of the hull itself; the lower end of these recesses will be provided with a gland, through which steel-wire rope (preferably of about 3 in. circumference, coated with mastic or some bituminous substance to render it smooth) will pass to two buoys, one to each recess; these I would make about 3 ft. in diameter by 2 ft. 6 in. deep, cylindrical and with dished ends (these would be full of air compressed to about 90 lbs., and this would obviate the need for strutting against collapse when diving). The top of the buoy would form part of the deck when the buoys were in. These buoys would each weigh about 4 cwt., and would have a lifting capacity of 5 cwt. over and above their weight—sufficient to take up 125 fathoms of 3-in. steel rope, with a breaking strain of 50 to 60 tons.

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* See sinking of U.S. submarine "Porpoise" in 127½ feet of water, page 121.

† And subsequent letter to the *Times*, April 5, 1907.

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"Inside the vessel a windlass to coil the forward and after rope would be provided, with a recorder showing what length of rope was out, also a pawl and ratchet and brake. I calculate that the whole of this apparatus, together with the extra strengthening of the hull at the points of attachment, would weigh less than 3 tons—1 per cent. of the weight of the submarine (when high and dry). The use of the apparatus is obvious. When the crew of a submarine find that they can no longer come up by altering flotation, they send up the buoys, which, as soon as seen by the attending ship, are hoisted up to the steam launch davits, and the ropes are hauled in with the steam winches till the conning-tower is above water. The load when the submarine is nearly free of water (the general condition for an hour or two) is a matter of a very few tons, so the rope provided is ample whilst the vessel is free of water, and the men are alive—and it is with the salving of these vessels during practice, immediately after they have gone down, and whilst the crew are yet alive, that I am concerned. I am not interested in salving submarines already full of water, and with drowned crews, some days after the disaster. Appliances capable of lifting 300 tons might then be necessary. A surface vessel requires bottom tackle or anchors. A submarine requires surface tackle, buoys, and steel ropes. One is as necessary as the other."

Every indication shows that submarine designers are fully alive to the necessity of providing more safety arrangements than was possible in the early types of these vessels. That their efforts will meet with success is the earnest wish of all those interested in submarine navigation.

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CHAPTER XVII.

MOTIVE POWER ON SURFACE.

It is hardly fair to compare the speed of the destroyer, which is the actual evolution of the first torpedo-boats, designed to carry the Whitehead torpedo, with that of the submarine, which has been in existence for so brief a period.

In the former, everything is sacrified to surface speed, whereas in the latter the motive power for surface running must be kept quite distinct from that required when the boat is working under water. This gives us two distinct conditions to satisfy.

1. Maximum speed on the surface. To obtain this it is necessary to have a built up forecastle to throw off the bow wave, a fine run aft, and great length compared to beam.

2. Maximum speed when submerged requires a form based something on the lines of the salmon. Nature teaches us that no excrescences, such as a forecastle or high conning-tower, are desirable. If these are provided, then under-water speed must be sacrificed.

That is, the requirements for obtaining high speed on the surface are opposed to those for obtaining the maximum results when submerged; again, if high speed on the surface is required, the submarine* must have greater length; to drive this extra displacement through the water means that increased motive power must be provided. This can be easily arranged for with regard to surface propulsion, but for submerged work a very large increase in the electric storage battery is necessary; this entails an addition to the weight out of all proportion to the extra speed gained. Therefore, at the present time, we are restricted in the matter of any great increase in length until some better form of motive power can be provided for under-water work than electricity. Most experts consider that the maximum speed is of more tactical value on the

* The diameter being assumed to be a minimum.

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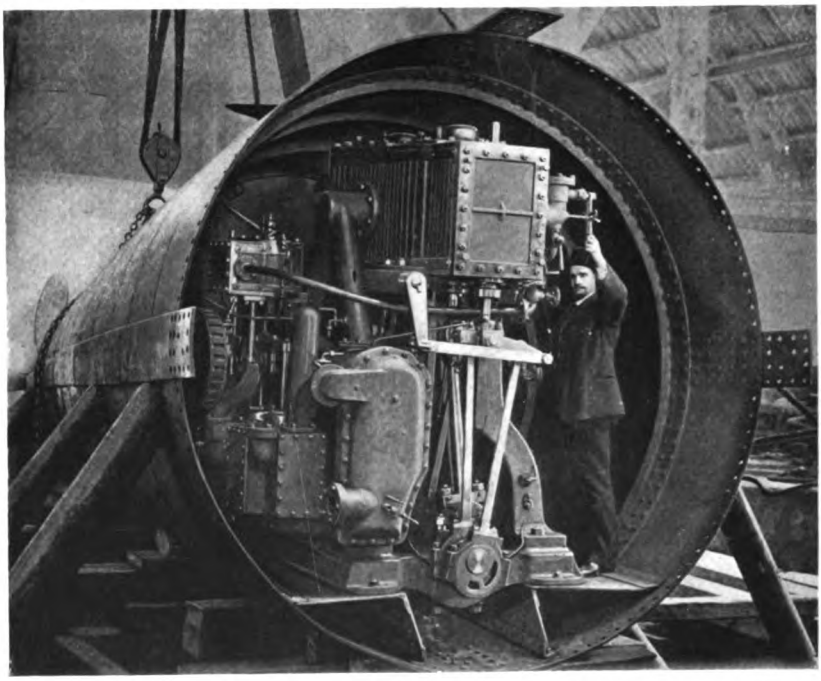
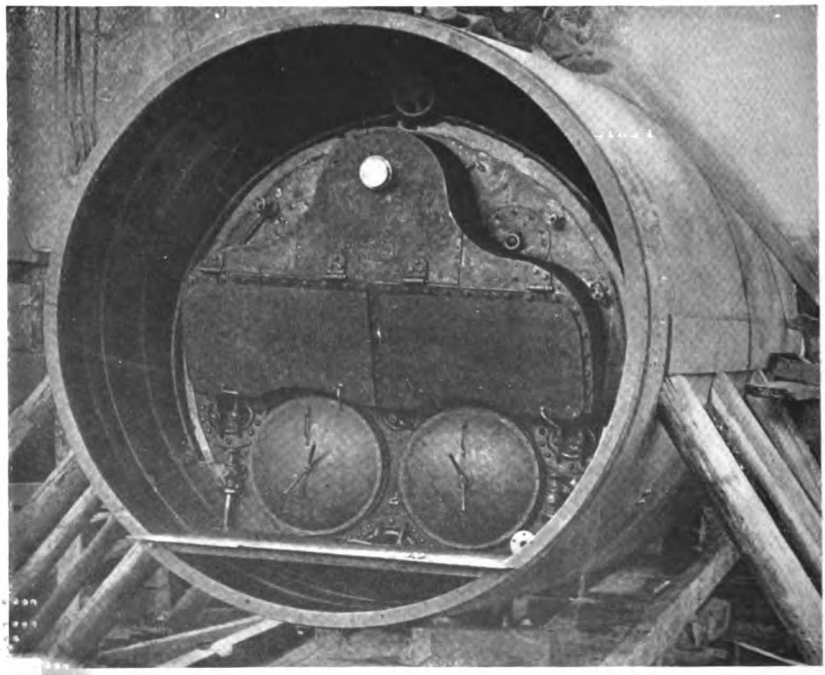


PLATE 72.—*NORDENFELT ENGINE OF "TURKISH SUBMARINE."*



3.—*NORDENFELT BOILER OF "TURKISH SUBMARINE."*

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surface than for submerged work, and are of the opinion that the majority of service requirements will be satisfied by giving the latter half to two-thirds of the former. For propelling agents we have at our disposal air, steam, electricity, petrol or gasolene, petroleum, crude oils, etc.

Air was tried in the French submarine boat "Plongeur," but, as we have remarked, is impracticable where a long range is required. The engine for the boat was built at Rochefort, from designs of M. Brun, and developed 80 H.P. when working at 180 lbs. air-pressure. It consisted of two groups of compound double cylinder engines, which were placed right aft, occupying a space of about 9¾ ft. long and 3 ft. in width The diameter of the cylinders was 12½ in. This system failed because a sufficient quantity of compressed air could not be carried in the small space available. The boat was capable of operating off the entrance to the port, but had low speed with very limited range, and the method of air storage at that time was not all that could be desired.

In Mr. Garrett's second boat, and all four Nordenfelt boats, steam energy was used for both surface and submerged work, because the storage of electrical energy was in a very crude state when these inventors first started their experiments, and the poor results obtained with the lead cell at that time did not warrant a large expenditure in this direction. The Nordenfelt engine for the small boat was of the surface-condensing type, with two cylinders and cranks placed at 90°, capable of working with a pressure of 100 lbs. to the square inch; this gave 100 I.H.P. The boiler was of the ordinary marine return-tube type, having one furnace and 200 square ft. of heating surface; in addition two hot-water cisterns, rhomboidal in body with spherical ends, were provided for the storage of steam energy for running under water; these are shown in Fig. 14. The boilers and cisterns contained 8 tons of water. All these tanks were tested to a pressure of 150 lbs. to the square inch.

On the surface the Nordenfelts were propelled in the same manner as any surface boat driven by steam. There was nothing out of the ordinary in the boiler and engines of these boats (Plates 72 and 73). Steam was taken from the boiler into the hot-water storage tanks and passed through tubes to give up its latent heat to the water in the cisterns, which held about 8 tons. The temperature of the

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water in these cisterns was maintained at that corresponding to a steam pressure of 150 lbs.

Before diving, the ash pit and fire door were closed, the funnel lowered, and the aperture sealed from inside the boat; water was then let into the buoyancy tank until the upper deck was awash. The submerging propellers were started as soon as the boat had only about 300 lbs. of buoyancy remaining and she was literally screwed under the surface of the water; the engines were started with the steam given off by the heated water. This was found during the experiments sufficient to enable the boat to run a distance of 14 miles.

The engines of the 100-ft. boats were also of the surface-condensing compound type, with two cylinders and cranks placed at 90°; with a pressure of 100 lbs. of steam, 250 I.H.P. was obtained.

The boiler, as in the smaller boat, was of the ordinary return-tube type, having two furnaces with about 750 square ft. of heating surface. The hot-water cisterns were the same shape as before, two in number, and containing 7½ tons of water each; these were placed on the fore-side of the midship section to counteract the engine and boiler, which were erected aft.

A buoyancy tank holding 7 tons was constructed under the conning-tower and used for bringing the boat to the awash condition The coal bunkers were fitted abaft the hot-water cisterns, in the middle of the boat; these held 7 tons of coal each, an amount which allowed the boat to keep the sea for five days at an economical speed of from 4 to 5 knots an hour.

In these kinds of boats, which depend for their operation upon the heat stored up in a large body of water, it was imperative that such heat should be generated by the making of steam in specially voluminous boilers, and in the last of the Nordenfelts, constructed at Barrow-in-Furness, the engines and boilers were made by Messrs. Plenty and Sons, of Newbury, and were specially built to suit the limited space available.

Steam energy was supplied to two high-pressure cylinders of 16 in. diameter, and two low-pressure cylinders 26 in. in diameter, all of 16-in. stroke, working on four separate cranks arranged so that each set of engines could be worked independently of the other; the working pressure was 150 lbs. to the square inch, the type being the inverted compound direct-acting surface-condensing; the condenser, was fitted underneath the crank shaft and formed the bed-plate.

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Steam was raised in two cylindrical boilers, with two furnaces to each, one being ordinary in size and the other quite extraordinary. Both were constructed with two flues, ordinary combustion chambers, and suitable return tubes for such; but whereas in the one case the boiler was 10 ft. 6 in. over all, in the other a total length of about 18 ft. was arranged for; this afforded the main storage of the boat. When the vessel was submerged the furnace mouths were made perfectly tight by means of a plate bolted on, the smoke-box doors were joined so that no hot air could escape into the interior.

The engines developed 1200 H.P. when running at 300 revolutions; for raising steam at short notice two fan engines were provided. The usual procedure in preparing for trials was to raise steam in the after or smaller boiler, and then discharge it as generated into the bottom of the forward one; the great body of water therein stored became charged with heat from the steam blown in.

As soon as the engineers were satisfied that the whole body of water had received all the heat which it would take up, the large boiler was isolated and carefully closed up against any possibility of leakage of steam, heat, or entry of cold air. When running on the surface, the main engines were driven by steam generated in the usual way by the coal fires heating up the after boiler.

To prepare for diving, the furnace fronts were closed by means of doors fastened with screws spaced close together, an asbestos ring being used to make the joint tight. The funnel was unshipped and passed into the interior of the boat, and the opening was closed with a special plate with an asbestos ring. The conning-tower hatches were closed and made water-tight by means of india-rubber joints.

Nordenfelt's boats were unpleasantly hot when battened down, but they did not suffer so much from excessive heat as the early French steam-propelled submarines. In the 14-mile test before the representatives of the Powers at Landskrona the temperature was measured on completion of the run, which lasted three hours, the boat being closed down, except for the funnel, and recorded as only 88° F.

The main points in Mr. Nordenfelt's system to which he drew particular attention were: "That by using water as the means of storing up energy a reservoir was provided that could never get out of order, and could be replaced at any hour in any part of the

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world, and without any extraneous assistance from shore or other ships. Whereas, if electricity were used, delicate and special apparatus would have to be employed as reservoirs of energy, such as accumulators or batteries, which, if they should require repair or replacement, would render the boat completely *hors de combat*, unless she were within reach of some electrical depôt. Also the durability of the cistern containing the water is immensely greater than any electrical apparatus, which, should a run of any distance be required, would still have to be provided with engines for the replenishing of their power. These objections also lie against the use of caustic soda or compressed air."

Besides, after carefully investigating what could be done in other ways, Mr. Nordenfelt was fully convinced that in no other method could so much energy be stored as by using heated water, especially as he had made it a point to design engines for his boats in such a manner that, as long as high pressure was provided in the boiler, expansion could be used, and as the pressure fell in the boiler by reason of the steam being used when under water, the engines could be regulated so that they would work well down to and even below the atmospheric pressure. The reason of all others which Mr. Nordenfelt said influenced him to adopt the hot-water system was the enormous factor of safety obtained by being able to blow out by steam pressure, without the use of machinery, large weights of water, which would lighten the boat and counteract any leak likely to occur; he also preferred to use the hot-water system because, the motive power being steam, ordinary marine engineers were at once familiar with it, and would have more confidence in the boat than if any new, delicate, or comparatively untried system were adopted.

With these Nordenfelts the inventor obtained some considerable degree of success, but the system was too slow; in the large boat it took two or three days to accumulate the required pressure in the hot-water cisterns for working the engines at their maximum speed for running under water. This is the reason why the method has not been repeated in more modern construction when steam was used for the motive power on the surface.

We have seen that the early modern French submarines, as the "Goubet," "Gustave Zédé," and "Gymnote," were pure submarines, having only one motive power, viz., electricity, for submerged running and movements on the surface. Their radius was limited to about

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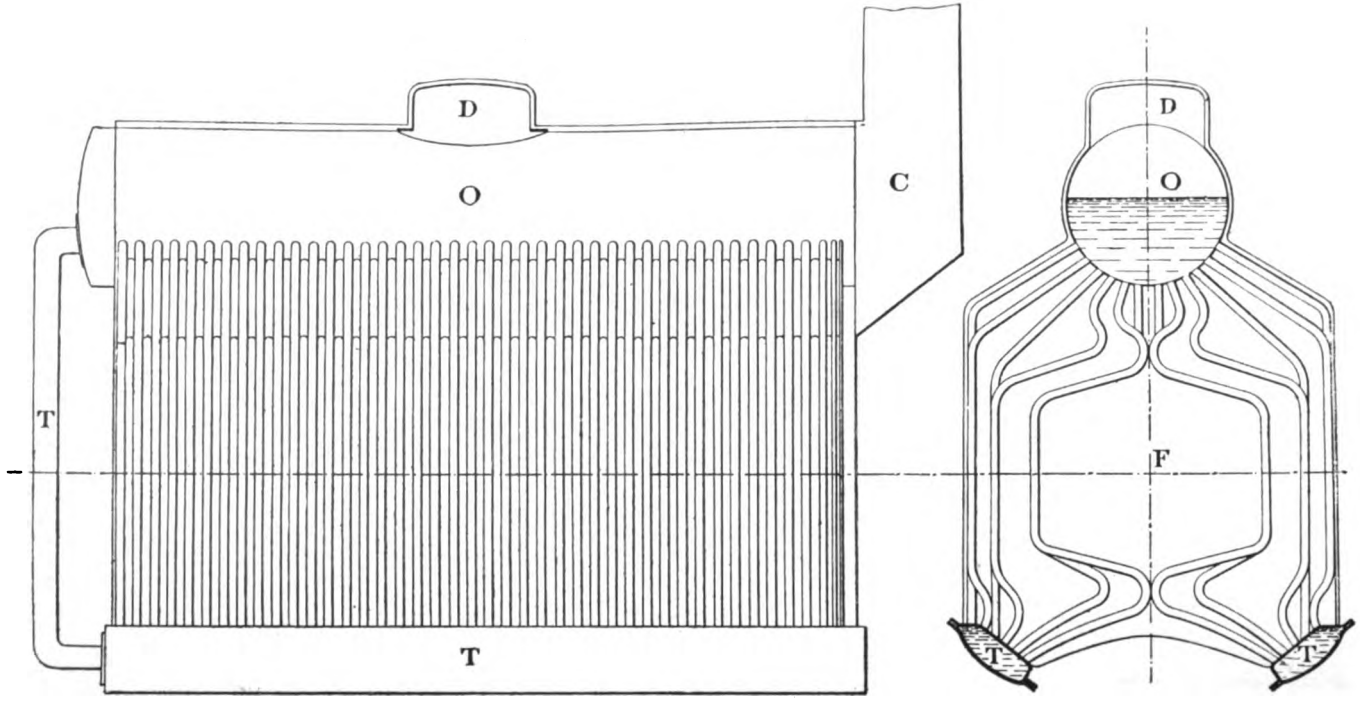

FIG. 39.—*NARVAL'S TUBULAR BOILER.*

C.—Funnel. *D.*—Steam Dome. *F.*—Furnace.
O.—Steam Reservoir. *T.*—Water Reservoir.

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30 miles. The "Narval" was then designed for more extended operations, and had a steam-engine provided for surface running of the triple-expansion type, constructed by Brûlé and Co.; the power developed is 250 I.H.P. The boiler is tubular, constructed by Seigle and Co. (Fig. 39), and heated by liquid fuel injected into the furnaces.

The arrangement shown in diagram is slightly different from the ordinary type of torpedo-boat boiler. In this design there was no difficulty at any time in keeping up the steam pressure for moderate speeds, but if a little extra was attempted it was difficult to get good combustion, and in consequence a large quantity of smoke was emitted, which was hardly a desirable feature in a modern submarine.

During some of the first trials, at Cherbourg, of these steam-propelled boats, the crews had a most trying time, the temperature frequently rising to as much as 122° F. This, with all ventilation closed, must have been most unpleasant. The men stood such severe tests well and seldom gave in, which speaks volumes for the personnel of the French submarine service. The time taken to close the funnel aperture and various ventilating arrangements was considerably in excess of that permissible for a boat under service conditions.

As we have seen, steam propulsion requires a heavy boiler, engine, and fresh-water tanks for its working; electricity alone necessitates storage batteries and heavy motors (which are described in detail in the next chapter), also a power plant in the boat, at a base or parent ship, to drive the motor as a dynamo for charging the cells installed on board. The capacity of this battery is small, and the range is therefore very limited.

The attention that has, during the last few years, been directed to the advantages of internal-combustion motors over steam and electricity for submarine work when running on the surface and awash, has been justified by the greater efficiency obtained by motors employing gasolene or petrol as a fuel in comparison with the steam-engine or electricity alone. The motor in most cases is coupled direct to the propeller shaft; it gives a very good H.P. for the weight, and allows of a much more extended range of action than that obtained with any other form of engine hitherto used in these boats. The heat energy that can be turned into useful work is as high as 28 per cent., nearly five times as much as steam. The advantages of this system summed up are:

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1. Large reduction in weight due to omission of boilers, steam pipes, feed-water tanks, etc.

2. No excessive rise of temperature in a confined space consequent on use of steam.

3. Constant renewal * of air inside the boat due to the requirements of an internal-combustion motor.

4. Space taken much less.

5. No smoke; the exhaust gases are nearly colourless, a light vapour, caused by the burning of the lubricating oil, can only just be seen.

6. Personnel is reduced to a minimum.

7. Greater facilities for starting and rapidly getting up power.

8. Total absence of steam escape, that tends to make the boat uninhabitable when using this power.

9. No waste of fuel when stopped.

Comparing the oil motor with the electric motor furnished with energy from the accumulators, we have a still greater saving in weight, less space required, also the range is very much superior.†

With gasolene tanks of large capacity modern submarines can travel for many hundreds of miles on the surface; the weight of fuel works out to approximately one-third of what it would be when using ordinary steam machinery for the same power; this enables the range of action to be very much increased for the same weight of fuel carried.

When running on the surface, various ventilators have to be fitted to keep up the supply of air for the gasolene engine, as all these types consume a very large quantity for complete combustion. This requirement is detrimental to submerged work, as very little air can be carried owing to the space required for storage being so limited. Therefore the gasolene engine is, for the present, ruled out of court when completely battened down, and we have to fall back on the electric accumulator, which requires no air in its working. Another advantage of electricity for submerged propulsion is that no loss of weight is involved when

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* This advantage refers to surface work only, and when comparing internal-combustion motors with electric motors, as the latter require no air. To obtain complete combustion in a furnace as fitted in the French submersibles of the "Sirène" class, about four times as much air is required than if internal-combustion motors were in use.

† In the proportion of 30 to 1 for equal weight (approximately).

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using the accumulators. If oil were used, all consumption would have to be compensated for, which is difficult, as it is extremely hard to gauge the amount. However, this is not insurmountable; no doubt automatic compensation could be devised for the purpose. We may therefore state that nearly all modern submarines use:

1. Internal-combustion engines on surface and for running awash.

2. Electricity furnished from accumulators to drive a motor for submerged work.

In considering the fuel used in internal-combustion engines we have a choice between several kinds. One of the chief producers of power is petrol or motor spirit—in America it is frequently called gasolene. Several kinds of petrol are on the market, but there is little to choose between the first-class brands. The spirit consists of the fractions having the lowest boiling points. It is separated by fractional distillation from the crude petroleum in the first instance, and thereafter subjected to a steam distillation in order to ensure its being absolutely free from oil matters, then it is treated with sulphuric acid and caustic soda to free it from any tarry or resinous matters which it may contain.

A good motor spirit distils over below the temperature of 220° F., and it is only by a fractional analysis that the suitability of a spirit can be determined, the specific gravity, 0·68 to 0·7, not being a sufficient guide in the matter. Up till recently the main source of supply for motor spirit was America, but at the present day large quantities of a good quality are being imported from Russia, Sumatra, Borneo, and Roumania.

Many hard statements are made about petrol. The spirit itself merely ignites with a hot flame, and does not cause an explosion. A red-hot poker can be placed in a tank of petrol and it will not even ignite; a white-hot poker will, however, cause it to do so.

The vapour itself is inflammable but not explosive. The danger lies in the vapour becoming mixed with a certain proportion of air. This mixture is highly explosive and dangerous; any spark made in its vicinity will cause an explosion. If this mixture is boxed up in a cylinder and compressed by the descent of the piston and then ignited by an electric spark, the resultant explosion is the motive power.

If a mixture of petrol vapour and air in the right proportions

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extends over the whole interior of a submarine boat, then if a spark from an open switch or other source occurs, an explosion, with usually disastrous consequences, will ensue. The one indispensable quality in the operators of this fuel is extreme carefulness.

There is no form of energy so compact and clean as petrol; a small tankful will enable a petrol motor to be driven for a considerable time.

Alcohol is constantly being advocated for use in lieu of petrol for submarine boats. The calorific value is less than that of petrol and would necessitate a somewhat heavier engine to make it as effective, also the cost would be higher. This latter disadvantage might be overcome with increased demand.

The efficiency of internal-combustion engines is largely governed by the degree to which the charge is compressed before ignition. The compression of a mixture of petrol vapour and air is restricted to a low limit of about 90 lbs. on sq. in., by its liability to premature ignition; with alcohol-air mixture a much higher pressure can be used with safety. The alcohol engine however seems slow in being developed in this country. France uses benzoline and heavy oils. A description of the engine for the latter is given on page 215. The disadvantage of heavy oil-engines is that the weights work out far heavier than when designed for the lighter oils, and this weight for submarine work must be cut down to the lowest possible mark.

In addition to the various kinds of fuels used, these combustion motors can be distinguished by the number of strokes made to complete a whole working period in the cylinder; this leads to a classification in cycles.

The engine employed in the Holland boat (Plates 74, 75 and 77) is usually spoken of as a four-cylinder gasolene engine worked on the Otto cycle. Practically all engines working on this cycle and using fuel which will vaporise at atmospheric pressure are developments of Daimler's original engines, they are the simplest and lightest of the different types, and work as follows:—

Stroke 1. Motion of piston in a forward direction for first time; air is drawn into cylinder with its proportion of gasolene vapour.

Stroke 2. Piston being brought backward for first time, resulting in compression of gases sucked in during first forward movement of piston.

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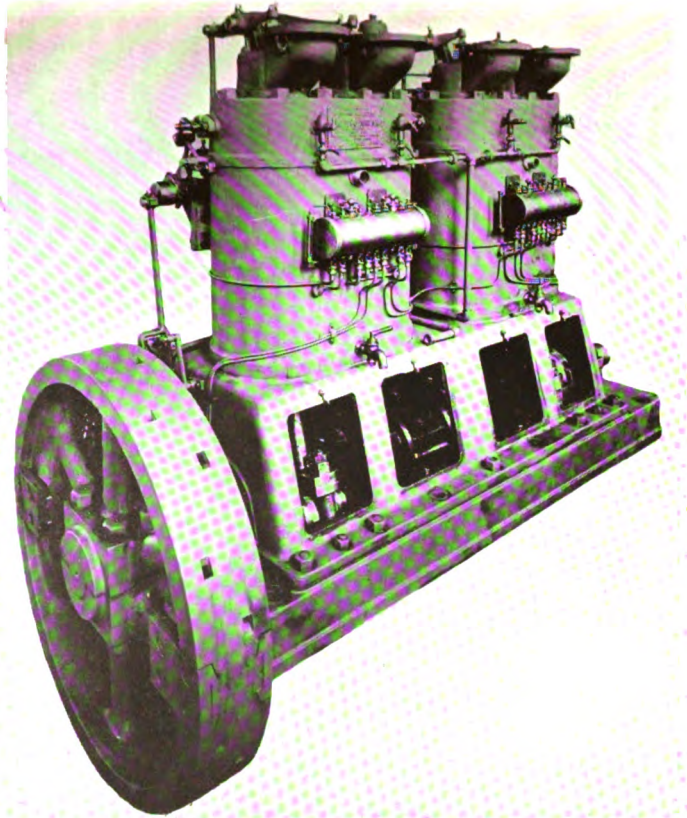

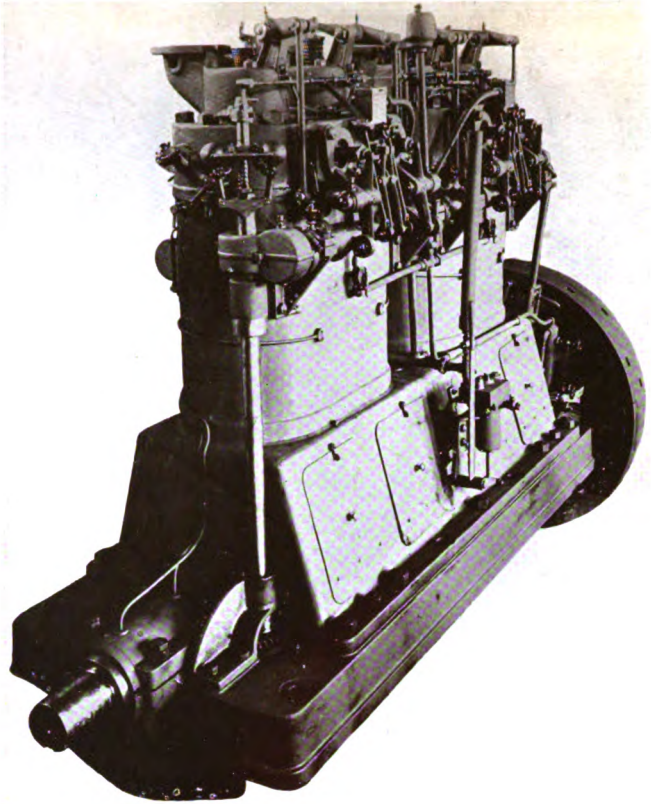

PORT SIDE. *STARBOARD SIDE.*

160 *H.P. GASOLENE ENGINE AS FITTED IN UNITED STATES SUBMARINE "ADDER" AND CLASS.*

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Stroke 3. Second forward motion of piston; the gaseous mixture is ignited by an electric spark. Expansion of gases takes place on the explosion, which results in work being done by piston moving down the cylinder; this is connected to a crank shaft and produces rotary motion.

Stroke 4. Second return motion of piston; products of combustion and exhaust gases are ejected.

Stroke 5. Similar to first stroke, a suck of gasolene being drawn in with air to form explosive mixture.

This is the commencement of a fresh cycle. It is therefore seen that one stroke in four is only really effective. Large fly-wheels are usually fitted which store up a considerable amount of energy, and help matters should the explosions become irregular.

In the Holland-Otto type 160-H.P. engine the four cylinders are fitted in pairs, each pair is surrounded by a water-cooling jacket, the water being circulated by a small pump sucking direct from the sea. The delivery pipe supplies water in the centre and nearly at top of jacket. The revolutions of the engine are about 320 per minute, with all four cylinders exploding regularly; this can be reduced to about 200 by altering the position of the cams. The consumption varies between 10 and 12 gal. per hour.

To prevent the products of combustion or consumed vapours of gasolene finding their way into the boat, the usual arrangement is to enclose the whole of the crank chamber, except for induction pipes fitted in different parts of the boat. The air is then sucked from either end of the crank pit by a pipe connected to the carburettor, the apparatus in which the petrol is vaporised. The admission and exhaust ports are worked by a 2 to 1 shaft revolved by skew gearing off the main crank shaft.

To start the Otto gasolene engine in a Holland boat:

1. See gasolene valves off.
2. See the igniter switches off.
3. Turn crank shaft until cranks are in best position for starting.
4. With hand pump force gasolene into supply tanks; when full, shut off.
5. See propeller clutched in.
6. Start moving crank shaft with electric motor, 3 having first been attended to.
7. Open gasolene valves and switch on igniter switches.

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8. As soon as explosions are taking place and the engine takes the load, switch off the electric motor.

Most of our first Hollands got through their endurance trials well, only a few cases of leaky petrol joints, etc., occurring.

The motive power of the American submarine "Protector" consists of a double installation of gasolene engines and electric motors, one engine and one motor on each of the twin shafts. These shafts are placed 5½ ft. apart and made of tempered steel 3 in. in diameter. As the electric motors employed in propulsion are located in the rear of the gasolene engines the shaft may be considered as being divided into three sections. At the extreme rear of each gasolene engine the shaft connects with the shaft of the motor by means of a 24-in. Frisbie clutch; 3 ft. farther aft is located a bearing for the shaft of the armature, and approximately 4 ft. behind the Frisbie clutch, which connects the dynamo with each machine, there is another similar clutch to unite the armature part of the shaft with the screw part which extends beyond the hull.

In the front part of this clutch, and on the starboard side, there is a cog-wheel to move the air-compressor. Towards the stern the shaft rests on several bearings, the thrust bearing being located 1½ ft. behind its union with the armature of the motor. Near this bearing, and extending to the rear, the shaft is surrounded with a perfectly adjusted bronze sleeve. Each shaft surrounded in this manner pierces the hull through a cast-iron stuffing box riveted to the hull and properly packed to avoid the introduction of water.*

The gasolene engines are of the four-cylinder, four-cycle type, of White and Middleton make, with certain modifications of Captain Lake's design, these latter having to do with the peculiar requirements of submarine work (Plate 76). The cylinders are 10 in. in diameter, the stroke is 1 ft., and the bases are water-jacketed. Each engine has a rated brake horse-power of 130. Ignition of the combustible is secured in no fewer than three ways, these being by dry-cell battery, by magnetos, or by a current from the storage batteries. No trouble has ever prevented the working of at least one of these alternatives.

The gasolene engines of the "Protector" (Plate 76) are fitted so

* Two water-pipes are led from circulating pump to main and thrust bearing for cooling purposes.

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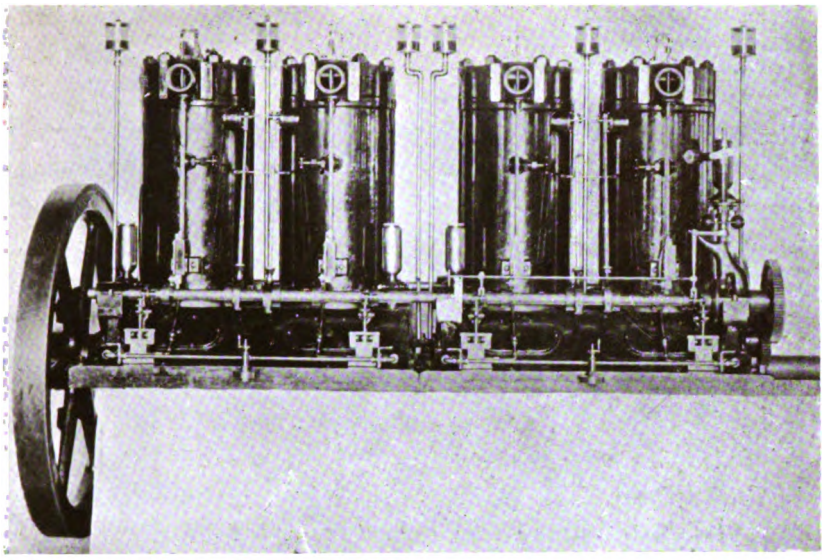

PLATE 76.—*WHITE AND MIDDLETON 130-H.P. GASOLENE ENGINE FOR SUBMARINE BOATS OF THE LAKE TYPE.*

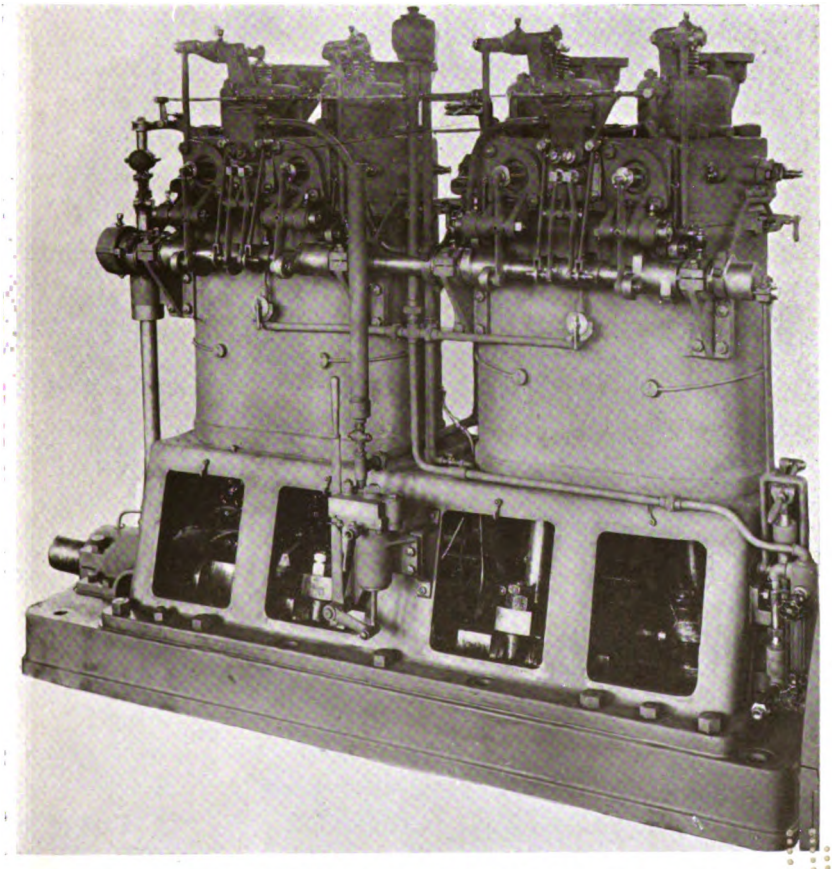

PLATE 77.—*160-H.P. GASOLENE ENGINE FOR BRITISH HOLLANDS.*

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that they can be used to propel the boat when she is running with only the upper half of the sighting hood above water; and it is further possible, as has been proved by practice, because of the peculiarly designed induction valve fitted thereon, even to make short, quick submergences under gasolene propulsion, the valve automatically closing when the boat goes under water. This is believed to be beyond the power of any other type of submarine boat now in existence.

The engines are guaranteed to give 1 H.P. for one hour for every pint of gasolene consumed; the capacity of the gasolene tanks will give this boat a range of 350 knots in light trim at full speed. Gasolene can always be taken into a ballast-tank and the range extended to a 1000 miles if necessary.

The floor of the engine-room is lower than that in the living spaces so as to afford ample head-room. The engines are placed on each side of the boat, leaving a central passage between them by which control and supervision of the machinery in all directions are afforded.

The methods of abruptly exploding a charge in a cylinder has grave objections of a mechanical nature; the increase of pressure is so sudden that the parts acted upon may yield suddenly to the stress and have a shock which may be detrimental to certain parts of the machinery. This leads us to a consideration of the Diesel type of oil-engine, in which perhaps the best example of a constant cycle is to be found. The engines are at present made vertical and work on a four-stroke modified Carnot cycle The inventor, M. Diesel, at first tried to follow up the Carnot cycle, but this was found impracticable, as about 200 atmospheres compression would be required if this was aimed at. The action of the engine is briefly as follows:

Stroke 1. On the first downward motion of the piston air only is admitted at the pressure and temperature of the surrounding atmosphere.

Stroke 2. This volume of air is then compressed during the first upward motion of the piston to 35 or 40 atmospheres; this raises the temperature to over 1000° F.

Stroke 3. On the second downward motion of the piston fuel is admitted for a certain period of the stroke and the combustion is carried out at a constant pressure for a period which is determined by the amount of oil to be sprayed in at 100 lbs. or so above the pressure

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in the cylinder; this quantity is controlled by the governor. The second part of the stroke is then approximately an adiabatic expansion.

Stroke 4. On the second upward motion of the piston the exhaust gas is expelled from the cylinder; the fifth stroke again is the same as the first, and so on. As to the size of these engines, a three-cylinder 500 B.H.P. has recently been completed at Messrs. Carel's works at Ghent, each cylinder to work at 166 B.H.P. It is anticipated that as the 500 B.H.P. engine has presented no great difficulty in designing, a 1000 B.H.P. engine will before long be constructed.

Diesel motors can utilise the less volatile oils because the fuel is sprayed into the hot air and then at once vaporises. There is no actual explosion, as the fuel is introduced into an excess of air and burns as it is injected. A gradual and complete combustion of the fuel takes place, resulting in a very high economy. The power can be regulated to a great nicety as the fuel is always burned at the same temperature but in varying quantities. The French Government had no great success with the benzoline motors tried in some of the submarine boats, therefore they turned their attention to the Diesel oil-motor, which was exhibited at the Paris Exhibition of 1900. As the French firms could not obtain the latest drawings of the engine, a committee of naval officers was sent to Augsburg to inspect and report on the latest type of motor turned out by the Diesel firm. This led to an order for six of these engines being placed for the French submarines under construction. While welcoming the triumph of German industry, the press of that country regretted that no German submarine at that time was ready for an engine; but since then a 160-H.P. Diesel engine has been delivered to the German Government, which is undoubtedly for the latest boat they have been secretly constructing at Kiel; so confidential is this kept that enquiries of officials in the Kiel naval yard resulted in the statement that they were not even allowed to know what was being built.

In Plate 78 a 160-B.H.P. Diesel engine of 40 B.H.P. per cylinder is shown; this is similar to the Diesel engine supplied by Messrs. Carel to the French and German Governments for use in their submarines. These engines run from 350 to 400 revolutions, and use crude petroleum with a flash-point of about 200 F., with a guaranteed consumption of 0·5 lbs. per B.H.P.-hour. The total weight is about 12 tons. As to the fuel used in this type, Scotch shale oil has

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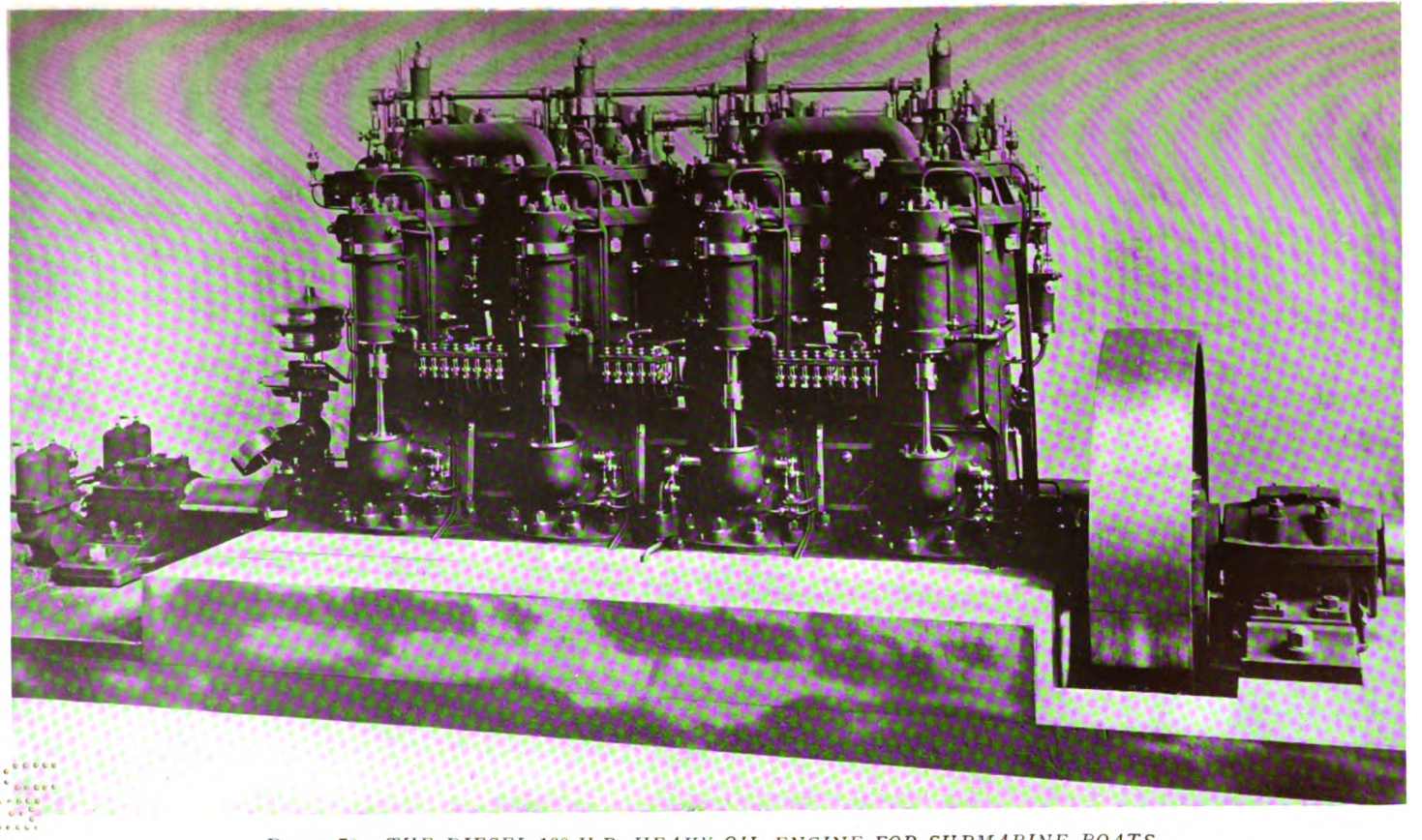

PLATE 78.—*THE DIESEL 160-H.P. HEAVY OIL ENGINE FOR SUBMARINE BOATS.*

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been found to be the cleanest and best, but many other brands can be used, the only precautions necessary being to see that these oils are desulphurised, and the freer they are from bitumen the better, as this tends to clog the valves and renders frequent cleaning necessary. With shale oil the valves do not require cleaning oftener than once a month, but with the heavier oils they must be cleaned about once a week. Paraffin-lamp oil is used after the heavy oils to be run through the valves for a few minutes before shutting down, in order to cleanse them, and may, if other supplies fail, be used in the engine exclusively. Creosote oil has been tried, but the analysis gives a much lower calorific value than for petroleum, while the amount of tarry acid—35 per cent.—was so great as to prohibit its use.

Heavy oil engines of the Gardner type are unsuitable for submarine work, as to make the oil vaporise freely one of two methods has to be employed.

1. By utilising the exhaust heat.
2. By continuous lamp heat.

The success of the first method is doubtful, because the heat evolved during different speeds is too erratic and uncertain to ensure perfect vaporisation; cracking of the oil is liable to occur unless special means are used to carry off the excess heat. The exhaust heat varies considerably when working at varying powers. The second method is unsuitable for submarine work as it is not permissible to have a naked flame in a boat with chances of hydrogen vapour about.

A patent has lately been taken out by a well-known English firm* which has reference to gasolene or other internal-combustion engines, more particularly for use in submarine boats, torpedo-boats, or other vessels. The engine has a series of vertical cylinders arranged in such a manner as to occupy a central position in the boat, while leaving ample space at each side and at the ends for the movements of the officers or crew. The number of cylinders may be varied according to the power required. In the case of boats having the form and dimensions which have been demonstrated to be most suitable for submergible torpedo vessels, the inventors have found that eight cylinders arranged in four pairs, working on the Otto cycle, are a very convenient number. The cylinders have trunk pistons, and are grouped together in two rows; the pistons of each pair are

* Messrs. Vickers, Sons and Maxim.

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linked to the base of a double triangular return connecting-rod. The crank shaft is built up with separate crank pins for each half of the double connecting-rod. The arrangement of the engine as specified allowed the exhaust to pass directly upwards from the upper ends of the cylinders.

In the accompanying illustrations, Fig. 40, 1, 2, 3 and 4, is shown an 8-cylinder engine as applied to a boat having a single screw. Fig. 40, 4 is a detail cross section showing one of the double connecting-rods. AA represents the cylinders, which are supported by columns BB. The latter are secured to bed-plate C, and the whole forms a rigid structure. Each pair of cylinders, together with a main bearing D, is cast or bolted together in a transverse line. Trunk pistons E are fitted to each pair of cylinders, and are connected by links or piston-rods F to the angles of the base of the double triangular connecting-rod F_1, which connecting-rod is held in position by means of a radius lever H_1 pivoted at H_2 to one of the columns BB. The crank shaft I is constructed as shown, with a separate crank pin J for each of the connecting-rods. The induction, exhaust, and gasolene or oil valves are operated by cams carried on counter-shafts N at the side of the engine. These counter-shafts are revolved by scroll gearing or toothed wheels and pinions actuated from any convenient part of the main crank shaft.

Summarising generally, the essential points which should be considered in petrol-engine design for under-water craft are:

1. No petrol vapour to find its way into the interior of the boat either by a leaky joint or unconsumed petrol leaking past the piston rings into crank pit.

2. Crank pit to be sealed, except for 3; leakage of foul gases must be reduced to a minimum.

3. The air for forming explosive mixture to be drawn from various induction pipes, placed at different parts of the boat for ventilation purposes, into the crank pit, and then led over the exhaust pipes to raise the temperature in engines that do not require cool air for their mixture.

4. Accessibility, simplicity, and durability.

5. Proper delivery of petrol into carburettor under all conditions of inclination in a heavy seaway.

6. Exhaust gases to escape with as little friction and back pressure as possible.

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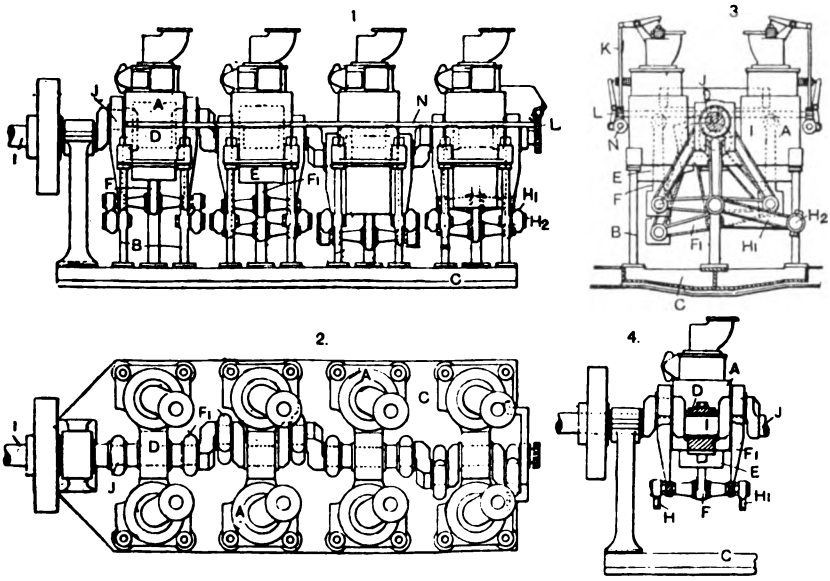

FIG. 40.—*PROPOSED GASOLENE ENGINE FOR SUBMARINE BOATS.*

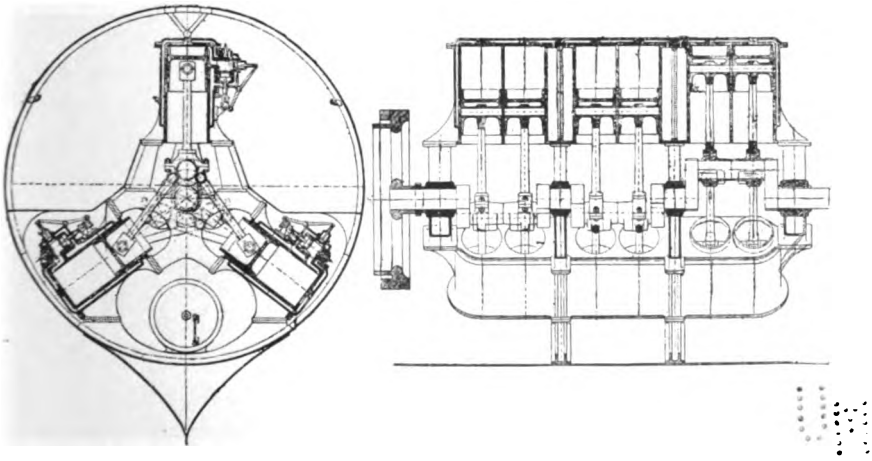

FIG. 41.—*18-CYLINDER ENGINE OF M. FOREST.*

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7. Balancing is of paramount importance to ensure steady running.

The objective to aim at in these oil-engines is to reduce the consumption to a minimum per horse-power hour, and uniform carburation is another important feature, necessitating a good carburettor; also it is advisable to get the greatest possible weight of charge into the cylinder during the suction stroke. If any attempt is made to increase the richness of the mixture to make up for the deficiency of power due to the cylinder not being properly filled, there is always danger of overheating the cylinder and causing premature explosions; efficient water jacketing is very necessary to dissipate any local heat.

The gasolene tanks for submarine work have to be built with great care and should be capable of standing a high-water pressure test, each rivet being inspected for weeping, etc. There are two systems of feed that can be employed, pressure and gravity.

The pressure feed is not in favour for submarine work as, in case of a leaky joint, free gasolene would be forced into the boat, and, when stopped, gasolene might be forced into the cylinders, which is undesirable; therefore gravity feed is that generally employed, and it is usual to fit a pump, worked off the cam shaft, to force the gasolene from the large tanks to a small gravity tank placed above the level of the carburettors.

With the Holland engine, when an igniter blows the engine has to be disconnected to prevent the unconsumed gasolene finding its way into the boat, otherwise crank-pit explosions will occur. The method of fitting the igniter is very crude, but no doubt will develop as igniters for other services are perfected. This igniter is one of the most essential features of this class of engine.

The water vapour always present, mixed with oil, etc., is very liable to break down the insulation both in low and high-tension circuits. To ignite the explosive mixture of air and petrol vapour, nothing is found better than a good secondary electric spark. This is better than a primary spark, as it breaks down any corrosion forming resistance on the electrodes of the spark gap plug. It is a very simple matter to increase the voltage from a 6-cell accumulator at 12 volts to several thousand volts. To do this, the low-tension current is passed through the primary winding of an ordinary induction coil; to the ends of the secondary coil are attached the points of the sparking plug across which the high-tension spark passes. A

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contact make and break is usually worked off the main or cam shaft. By inserting condensers in the secondary winding a much heavier spark is obtained if required.

Another system is to use a small magneto, which is a small armature revolving between the pole pieces of an electro-magnet. Sometimes the armature is made to rock and not rotate. This cuts the lines of force and gives a difference of potential at the brushes, which causes a current to flow in the circuit and gives a spark across the points of a sparking plug. It therefore follows that the spark varies with speed of rotation. If the engine is going slow and any deposit occurs on the spark plug points, sufficient voltage may not be generated to break down the increased resistance, and in this case the sparks would fail. Therefore at low speeds the ignition run off accumulator cells is preferable and is always ready, which is a great advantage. All wiring should be as short as possible in the ignition systems.

Reversing gear of these engines is as yet inadequately developed. Reversing propellers have been tried, with very poor success; usually the gasolene engine is stopped and the shaft run with the electric motor in reversed direction for going astern. This is only required in very close waters or going alongside a berthing jetty, etc.

When the engines are running, a curious threshing noise is heard; this, inside the boat, sounds loud, but a short distance away can scarcely be heard. The internal-combustion engines used for the "A" class British submarines are mostly of the Wolseley make; they have twelve cylinders and develop some 600 H.P. Their dimensions I do not give, for obvious reasons, though some idea of the size can be gathered from the fact that the exhaust valves are 5 in. in diameter, and the petrol consumption is about 70 gal. per hour.*

In introducing the naval estimates before the House of Commons on March 6, 1905, Mr. Pretyman gave some information respecting the submarines by saying: "The original type of boat was 150 H.P., and had a speed of 7½ knots on the surface. The new type is 850 H.P., the speed 13 knots, and the radius of action 500 miles, the below-water speed being 9 knots, with 10 hours' endurance. The boats dive dynamically, not statically, and the motive power below water is electricity."

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* Details given in the *Auto-Car*, January 21, 1905.

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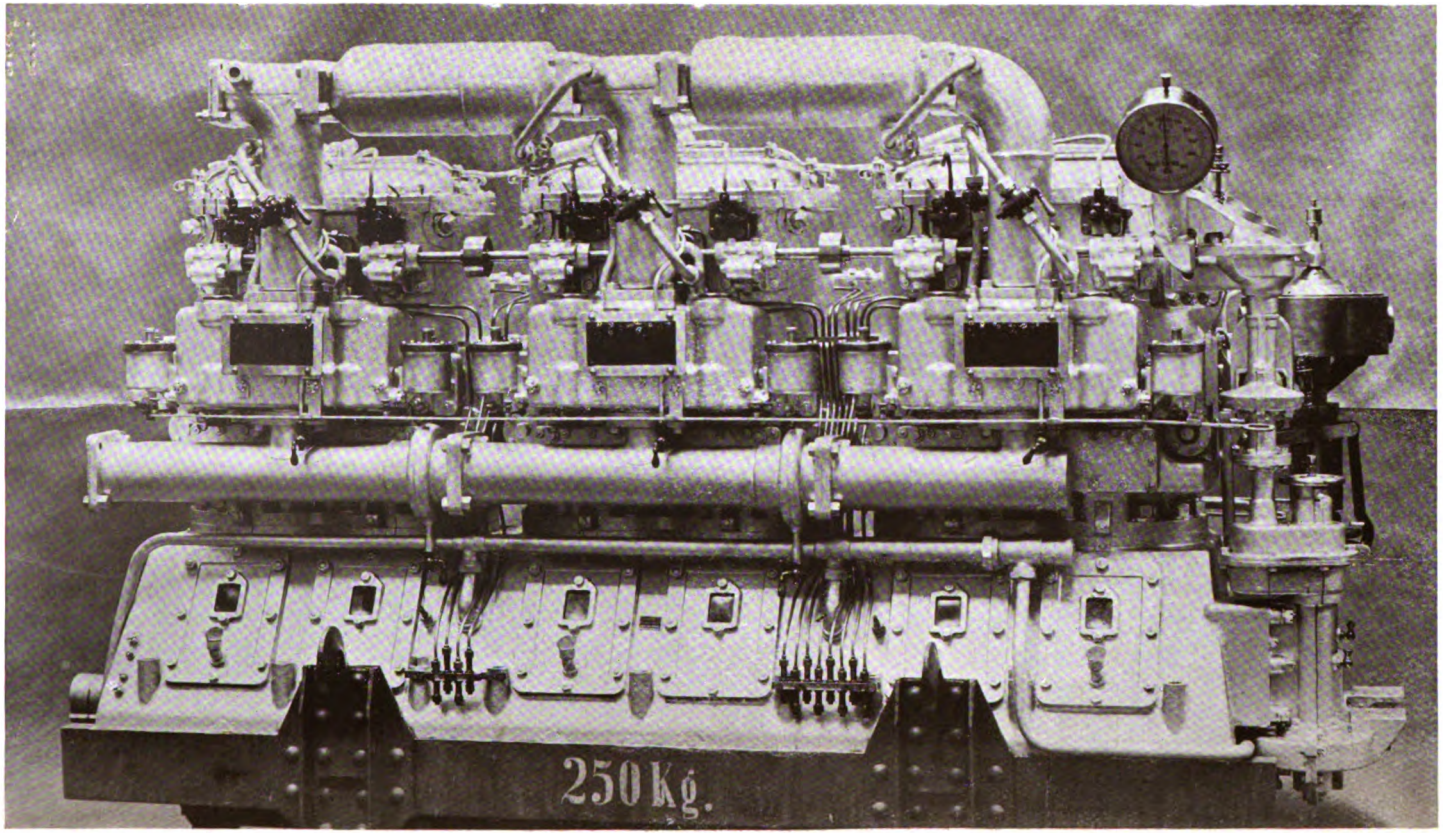

PLATE 79.—*A KÖRTING 250 H.P. SUBMARINE ENGINE, INLET SIDE. NOTE RECEIVER CHAMBERS WITH INSPECTION COVERS OFF, ALSO HOT AIR PIPES FOR STARTING OVERHEAD; WORKING AIR PIPE BELOW.*

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Amongst the disadvantages of these internal-combustion engines may be mentioned the limitation of cylinder capacity. It is found by experience as the capacity of the cylinder is enlarged the heat of combustion is intensified in an excessive proportion, therefore the water jacketing must be very carefully considered; the trouble usually found is to keep the water circulating freely and avoiding dead water.* Again, in working with large cylinders, the compressions in lbs. per square inch have to be lowered considerably to prevent pre-ignition. In small automobile engines a short stroke and high piston speed has been developed. This would not do in submarine work, as the heating effect would be too great owing to the high number of explosions per minute, therefore most countries are developing moderate engine speeds and cylinder capacities. In this way power can only be obtained in coupling a large number of small engines together. To show the method adopted, a diagram (Fig. 41) is given of the 18-cylinder 500-H.P. system designed by the French engineer, M. Forest. The arrangement consists of three groups, placed 120° apart, the 18 pistons being connected to the same crank shaft. This distribution is useful as it permits one or two groups being entirely stopped or reduced; thus the power can be varied from 50 to 500 H.P.

Another type of heavy oil-engine is the Hornsby-Akroyd. This competed for the War Office prize. The traction engine passed every test and did the ups and downs of road-work in crossing five counties. These engines have yet to prove their value for submarine propulsion.

A Hirsch-Low engine, on the same principle, enabled the 40-ft. surface boat, "Abiel Abbot Low," to cross the Atlantic; therefore, if developed, this type might have a future for submarine work. These engines, like the Diesel type, escape the difficulties of carburation and ignition by injecting the fuel into a chamber forming the extremity of the cylinder, which is maintained at a high temperature, and the air is introduced separately. By a mechanical arrangement of levers attached to this chamber, compressions, varying according to the fuels employed, can be utilised.

* The troubles with dead water, and consequent heating up of cylinder bonnets, were forcibly brought home to us in the first experiments with "A 1's" multi-cylinder gasolene engine.

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Moreover, the crudest forms of oil, obtainable almost anywhere at a few pence per gallon, may be used, and the heat of the chamber is sufficient to ignite the charge on compression. In this engine it is only possible to work with a low compression to avoid premature ignition, and therefore the type is necessarily a heavy one, and not at present suitable for submarine propulsion. To start this engine, light petroleum is used, and when the cylinder bonnets are well warmed up the heavy oils can be reverted to.

The German firm of Messrs. Körting have recently turned their attention to oil-engines for the use of submarine boats, and exhibited at the last Berlin exhibition a 250-H.P. six-cylinder two-stroke oil-engine (Plate 79); but though it was then impossible to obtain any accurate details concerning it, further particulars * are now available. The principle on which the engine works differs in several points from the usual two-stroke practice. The charge is not compressed in the crank chamber, but in special receivers by means of pumps, whence the air passes to an ordinary form of spray carburettor—a separate one being fitted to each cylinder—and thence to the cylinders, access to which is by ports, as in other two-stroke motors. The motor is designed to run entirely on paraffin, the carburettors being suitably exhaust-jacketed. In Fig. 42 can be seen such an engine fitted to a submarine, showing clearly the central gangway. The cycle on which the engine works is slightly different from the one ordinarily followed, the chief feature being the injection of pure air at the commencement of the filling of the cylinder, so that the exhaust gases are to a certain extent blown out of the cylinder by the pure air, and a higher efficiency obtained than usual. Fig. 43 depicts the parts in their chief positions throughout a complete cycle. On the up-stroke a full charge, which is assumed to be in the cylinder, is compressed, whilst the upward movement of the piston produces a reduction of pressure in the crank chamber. As the piston rises it uncovers the carburetted air inlet A, so that a mixture of paraffin and air is drawn into the crank chamber. As it rises still higher, as shown in diagram, a small port B is put into communication with a pipe C leading to the crank chamber, by means of a recess D formed in the piston after the manner of a D slide

* Extracts taken from *Motor-Boat*, *Auto-Car*, and details kindly furnished by the Körting Co., 1907.

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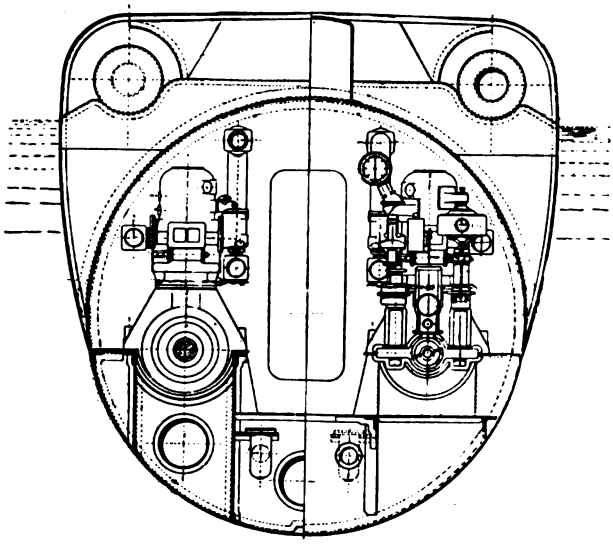

FIG. 42.—*KÖRTING'S SUBMARINE ENGINE IN POSITION.*

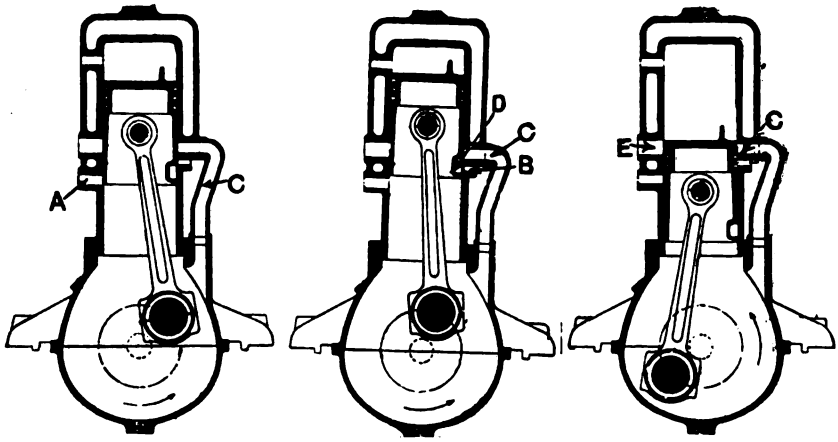

FIG 43.—*DIAGRAM SHOWING THE CYCLE OF THE KÖRTING ENGINE.*

A.—Carburetted Air Intake.
B.—Port leading to C.
C.—Pipe connecting Cylinder to Crank Chamber.

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valve in a steam-engine. It will be noted that the uncovering of these ports takes place nearly at the top of the stroke. Pure air is then drawn into the pipe C, but not to any great extent into the crank chamber. Directly the charge is fired momentum is imparted to the piston, which covers all the ports in the cylinder walls, and expansion of the charge takes place in the usual manner. Towards the end of this working stroke the exhaust port E is opened, and afterwards the port C, so that the pressure set up in the crank chamber, due to the downward movement of the piston, injects the pure air which is in the pipe C into the cylinder, which then blows across the face of the piston and scavenges the cylinder. The carburetted air in the crank chamber follows the air up the pipe C into the cylinder, and the same cycle is repeated.

For control purposes a centrifugal governor is used acting upon throttle valves arranged in the pipes C of each cylinder. It has hitherto been somewhat difficult to employ paraffin for work in submarines through various causes, and without using the lighter oils for starting, etc. An electric motor, which normally can be used as a dynamo, is keyed direct to the crank shaft; in this way the crank shaft can be driven for a few minutes at starting, whilst air is drawn in over an electric heater. The paraffin is not turned on until the engine has been driven four or five minutes and has warmed up; as soon as the paraffin is turned on it is found that it vaporises freely, and that starting is rendered easy without the necessity for using either an open flame or light spirit.

As regards structural details of the motor, it is interesting to note that piston-rods and crosshead guides are employed, whereby side thrust on the cylinder walls is entirely eliminated. The crank case, which is of phosphor-bronze, has been provided with celluloid inspection covers; the cylinders are cast in pairs, but each pair has a separate air-receiver. Probably this engine, or a similar one, has been installed in the German submarine of M. d'Equevilley, built at the Krupp-Germania works, and also this type, or a Diesel engine, in the boat being constructed for the German Government at the same time.

The French naval authorities have been of late considerably exercised as to the most satisfactory motor for surface propulsion to adopt for the large number of submersibles now under construction. Many proposals have been put forward, and even a return to steam

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has been contemplated unless a better motor than "à explosion" is forthcoming. Considerable advances have been of late made in the application of steam as a motive power for the lighter forms of engines for self-propelled vehicles, so it is not unlikely a satisfactory steam-engine may yet be designed for submarine work.

The successes obtained with the petrol motor surface boat will have a beneficial influence on engine design of submarines; but it must be remembered that the high speeds obtained with the former are not so much the advantage of petrol over the steam, but due to the skimming form of hull adopted. The boats are usually designed with nearly a flat bottom and a rising bow to meet waves; as speed is increased the boat tends to rise out of the water; if trimmed by stern the tendency is to bring her well out of the water, and in this condition she eludes the maximum resistance of partially submerged bodies. The reason the Mediterranean motor boats* failed was chiefly owing to the petrol engine not being designed to run at a reduced speed, etc., and the boats had to go at nearly full speed in a heavy seaway, which of course ended in a disaster. The incontestable efficiency shown by various designs of oil-motors in the last few years shows there is a great future before them for all sorts of naval work. Besides cutters, picquet boats, pinnaces, submarine boats we may expect petrol and petroleum-driven torpedo-boats of very high speed.

Petrol surface boats even now are very reliable. Mr. Edge states that his petrol yacht recently ran from London to Lerwick† for five days and nights without the engine stopping, during which time she covered 560 miles, and still had enough fuel on board to carry her another 2000 miles.

If the points only too inadequately brought out in this chapter are carefully reasoned out on a pure engineering basis, I think the conclusion would be that a heavy oil-engine is the ideal for submarine work. Petrol is essentially the fuel for a fast-running, light, well-ventilated engine; and when the real danger of using petrol in a confined space, such as a submarine presents, is realised, it may be safely assumed that the petrol engine is only an intermediate stage in the development of suitable engines for surface propulsion of submarine vessels.

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* Mediterranean motor-boat race, 1905. † Shetland Islands.

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CHAPTER XVIII.

MOTIVE POWER SUBMERGED.

As has been mentioned in previous chapters, the energy for submerged work is provided by means of electric storage batteries made up of a number of cells or accumulators of the lead type, and electric motors are employed for propulsion, ventilation, pumping, and other purposes.

In brief, an electric storage battery of the lead type consists of two lead plates suspended in a vessel containing water mixed with sulphuric acid; this solution is known as the electrolyte.

An electric current is passed from one plate to the other and causes a chemical change in the constituents of the cell; one lead plate becomes coated all over with a brown powder usually known as peroxide of lead PbO_2. If now the electric current is removed and the two lead plates are connected by an external wire, a current is produced in the opposite direction, and one-half of the lead peroxide forms on the other lead plate, coating it with lead monoxide PbO. Both plates are now alike, and the current stops. The current generated is considered to flow from the plate, which is acted upon through the electrolyte to the plate unacted upon, then by the external wire back to the plate that was acted upon.

If this external wire is severed, the end in connection with the plate acted upon is the negative pole and the other positive.

The battery, after being supplied with a sufficient quantity of electrical energy, is "charged,"* and subsequently, when it is desired to utilise the stored energy, the former chemical action is reversed and the battery is "discharged."

Planté first put forward the lead cell for conversion of electrical energy in 1859, and ever since then shoals of inventors have been hard at work in trying to perfect it. Most of these efforts have only

* "Charging" constitutes a conversion from electrical to chemical energy.

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resulted in small improvements, and were chiefly noticeable towards the end of the eighties of last century; by this development under-water navigation has become a thoroughly practical matter.

The advantages of the electric-accumulator system for submerged work are:

1. The electric propulsion motor, which has its energy furnished by the battery of accumulators, requires no air.

2. The motor runs noiselessly, and where gearing is used, the noise from this can be heard for a short distance only.

3. The battery gives off practically no gases when in use; in some cases hydrogen gas is supposed to cling to the plates and to have been released when in a seaway. This, however, is a moot point. (See chapter on Fumes.)

4. The electric motor assures an invisible course when the boat is running under water.

The disadvantages are:

1. Injury by overcharging, or over-discharging.

2. Great weight; a ton of battery and electric motor will not give more than 7½ to 8½ E.H.P. hours. Therefore, to propel a boat 100 ft. long, of maximum diameter 12 ft., through the water 10 knots for three hours would take about 100 tons for battery power alone.

3. Durability is poor as the sulphuric acid action on the lead is violent and tears the material down; this necessitates renewal every few years.

4. Skilled labour is required to attend the batteries to prevent 1.

The conditions these batteries are subjected to are of the severest; it is impossible to conceive a worse place electrically than a battery tank in a submarine boat. The surroundings are moist with scarcely any ventilation, and that forced. The weight is excessive, which necessitates the cells being carried in the bottom of the boat to keep the centre of gravity low. The space is very limited, consequently they are cramped; in fact every evil is present. These drawbacks were pointed out in connection with the Spanish submarine boat, "Peral," but were not appreciated, and consequently led to Lieutenant Peral coming to loggerheads with the authorities over the heavy expenditure in this direction; the "Gustave Zédé" was very unfortunate with her battery at first. Since then, however, storage battery work has become better understood, and so we may lay down, therefore, that if the cells are carefully looked after, and the

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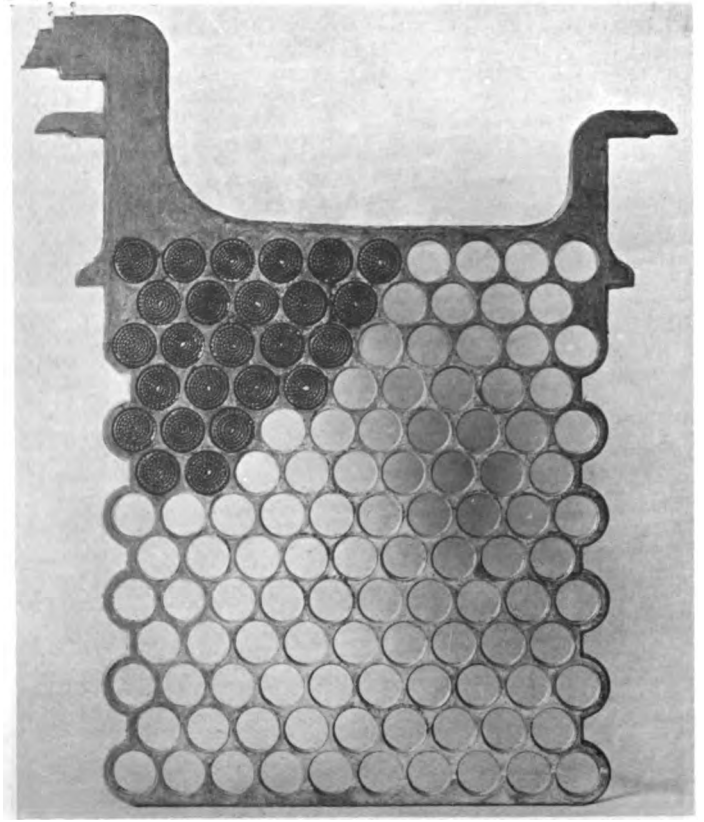

PLATE 80.—*CHLORIDE POSITIVE PLATE, EXIDE TYPE. SHOWING A FEW ROSETTES IN POSITION.*

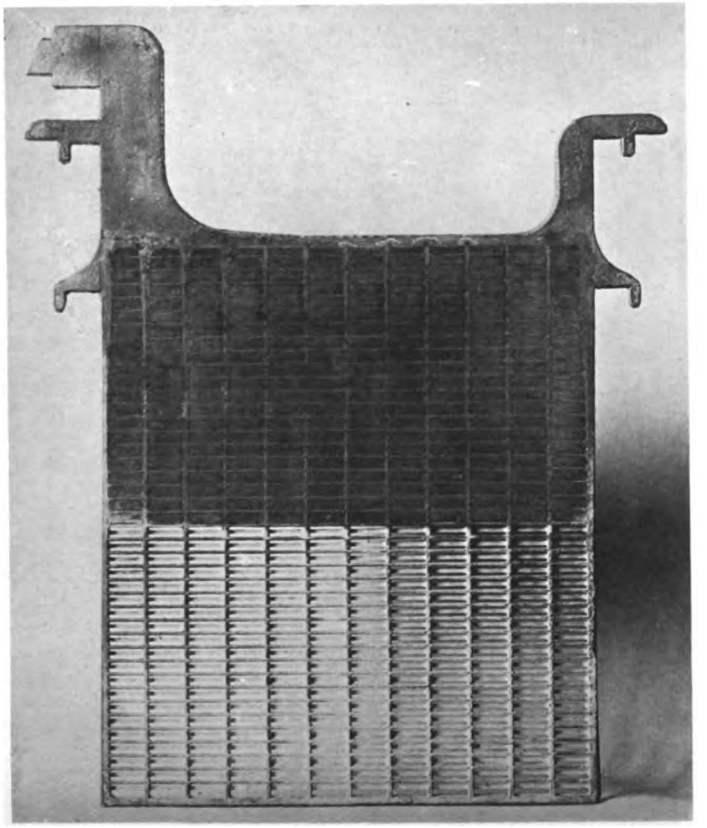

PLATE 81.—*CHLORIDE NEGATIVE PLATE, EXIDE TYPE. UPPER HALF COMPLETED WITH PASTE. LOWER HALF READY FOR PASTING.*

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number of complete cycles of charge and discharge are not excessive, they should last from four to five years.

Notwithstanding its many disadvantages, the accumulator system is at present the only suitable method of storing energy for propulsion under water. Many forms of these batteries are in the market, but they all possess the great disadvantage of having great weight in comparison with storage capacity, and to obtain anything approaching a long life for the accumulator a slow rate of discharge is necessary.

There are two kinds of storage batteries: (1) the Planté type, in which lead plates, either plain, corrugated, or honeycombed, are used, and the active material is formed out of the plate itself; (2) the Faure type, in which the active material is formed out of a lead paste pressed into corrugations or cavities in a cast lead plate which form the electrodes.

Taking a chloride cell as a typical example of an efficient accumulator, we notice in manufacture that the construction of the positive plate is quite different from that of the negative plate.

The chloride positive is not, strictly speaking, a Planté plate, in which the frame of the plate forms the active material, nor is it a Faure plate, in which paste applied to a lead frame is converted into active material, but it is a combination of the two principles, insomuch that the frame remains unacted upon, while no paste enters into the composition of the plate, but the active material consists of a skin formation of peroxide on metallic lead rosettes firmly held in position in an antimonial lead grid (Plate 80).

The true Planté positive has the disadvantages that the circulation of the electrolyte is restricted through lack of porosity in the plate, and also, since the plate itself is acted upon to form fresh active material, the metal disintegrates in the course of time. For the same reason the conductivity of the plate gradually decreases as the metallic lead is changed into peroxide.

The true Faure positive plate again is mechanically weaker and unable to withstand heavy fluctuating work so well as the Planté plate, and the paste is liable to disintegrate and entirely detach itself from the frame of the plate.

It is considered that in the chloride positive these troubles are reduced to a minimum. The plate is highly porous, the conductivity remains constant throughout the life of the plate, and there is no risk of

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disintegration, as the active material is a mere coating of peroxide on the face of mechanically strong metallic strip lead rosettes.

The first step in the manufacture of the positive plate is the casting of an antimony-lead alloy grid or frame. The mould for these castings is operated by hydraulic power, and the molten metal is run into the mould under an air pressure of 150 lbs. per square inch, which secures a homogeneous casting. The grid obtained is a framework with a number of circular holes about $\frac{3}{4}$ in. in diameter each, tapered from both sides towards the centre, and the grids are then taken to a multiple punching machine, which in one operation trims all the interstices.

The next process is the manufacture of the pure lead rosettes. For this purpose molten lead is run into a steel cylinder and almost allowed to solidify. Having reached this condition, a powerful hydraulic ram is brought into operation which forces the lead through two slots at the bottom of the cylinder, so that it emerges in the form of tape about $\frac{3}{8}$ in. wide, which is wound on to drums.

The lead tape is afterwards taken to a "gimping" machine, which automatically passes the tape between suitable rollers, forms ribs on one side of the tape, cuts it into lengths and rolls it into rosettes. Each of these machines is capable of turning out 3000 rosettes per hour. These are placed on a template and the before-mentioned grid is placed over them so that, on placing under a press, the rosettes are forced into the holes of the grid; but in order to ensure perfect contact between the grid and the rosettes, the plate is subsequently placed under another hydraulic press, which exerts a pressure of 200 lbs. per square inch. The plate is then "formed." This process consists in electrolytically converting a small portion of the pure lead rosette into peroxide of lead, which constitutes the positive active material.

The chloride negative is prepared as follows. Lead chloride is reduced to a liquid state by raising it to a very high temperature and is then poured into moulds, which form it into pastilles of a desired shape and thickness. These pastilles are then laid in a plate mould fitted with small studs to retain the pastilles equidistant from one another, and the mould is then placed in a hydraulic press. A nozzle is inserted and lead is squirted into the mould under a pressure of 150 lbs. per square inch.

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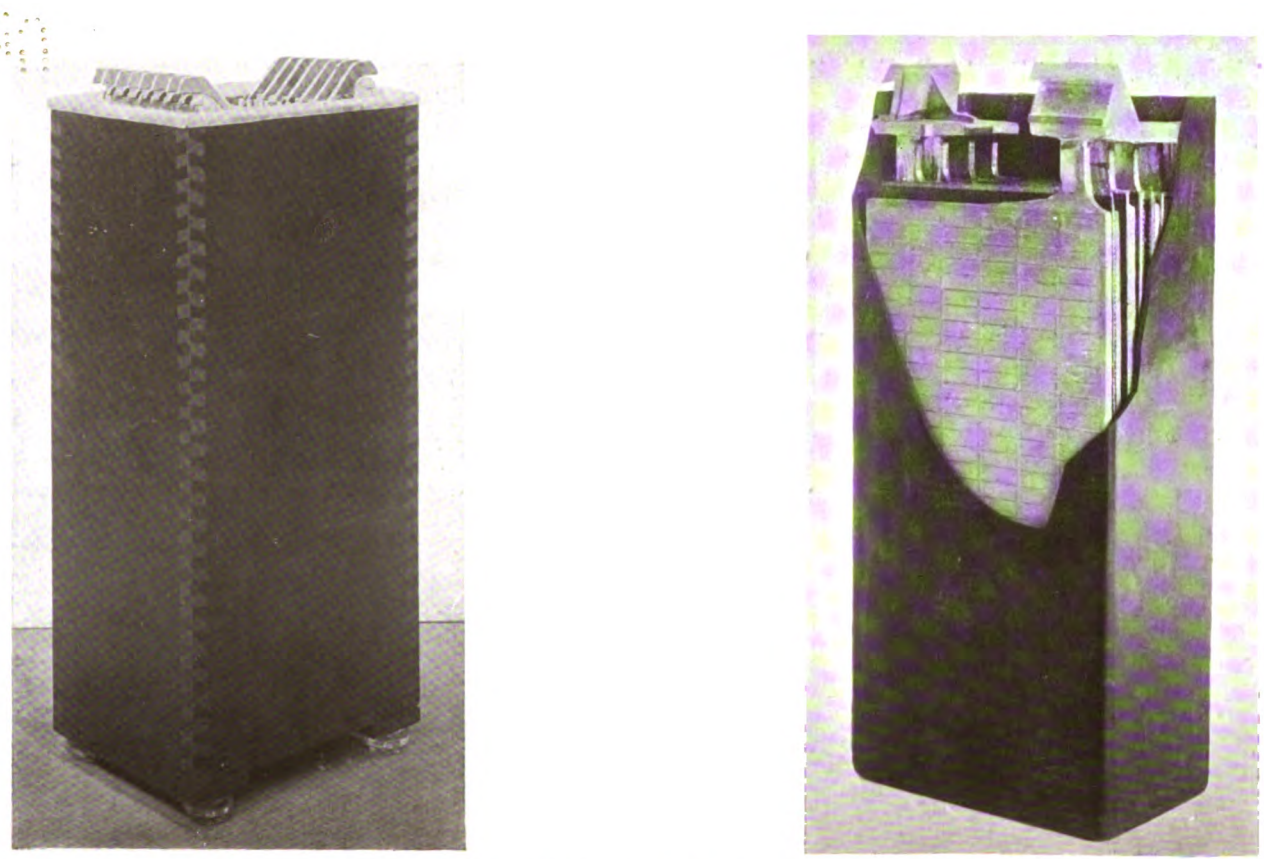

PLATE 82.—*TYPICAL ELECTRIC ACCUMULATOR CELLS OF THE LEAD TYPE.*

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The resulting casting is a lead plate holding the chloride pastilles, keyed in the frame in a series of V-shaped grooves.

To complete the plate as the negative of a storage battery, it is necessary to convert the lead chloride into pure lead, which is effected by setting the plates up with zinc plates as primary cells, and finally giving the plates several washings and hydrogen baths to remove all traces of chlorine.

Another type of chloride negative is the "exide" plate. The grid is also cast, but in a different manner from that of the positive, as it is much lighter and, when in actual use, is not subjected to the same stresses as the positive grids. It consists of a series of narrow vertical cages, the bars of which are horizontal and of triangular cross section, with the apices coming flush with the faces of the grid. The divisions between the cages are of solid metal, to give strength and rigidity to the plate. These grids are filled with a special litharge paste, which is mixed in a machine and pressed into the grid by hand. The plates, after being allowed to dry, are set up as negatives in forming tanks containing dilute sulphuric acid, and a current is passed through until the litharge is all converted into spongy lead (Plate 81).

The exide negative has been substituted for the chloride "hexagon" negative for all ordinary work, but for special work the chloride negative is still employed, the pastilles consisting of four small square pastilles joined together by a central web, so forming one large pastille, which is keyed into the frame of the plate.

The acid for filling these cells is supplied in carboys, already diluted to the requisite strength of 1·215 specific gravity.

For transport, this acid is shipped pure at specific gravity of about 1·840, and before use is diluted * to 1·215. Sufficient time should elapse after mixing to allow it to cool before filling the cells.

To take densities, battery hydrometers are supplied graduated from 1·150 to 1·250, the correct density, namely, 1·215, being marked in red. The instrument is marked in thousandths, which enables a fairly accurate reading to be taken.

Typical accumulator cells are shown on Plate 82, with all the plates connected up and provided with ebonite or glass rods for separating the positive from the negative.

* With pure distilled water, free from ammonia.

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The storage batteries of the American Hollands consist of sixty cells of about 1840 ampère hours capacity, usually of the chloride type; these will furnish 75 E.H.P. for 3½ hours at 120 volts, and drive most of the class at a maximum speed of 6·5 to 7 knots when submerged. This gives a radius of over 25 miles at 6 knots. The battery can be charged from the gasolene engine of the boat or from a dynamo carried in a depôt ship or erected at a base on shore. When building up the battery great care is necessary to insulate the containers from the steel hull of the boat.

In the Lake boat, "Protector," the storage battery compartment is mainly under the crew space, the floor of which is worked in transverse rabbeted strips of oak, alternate strips being easily removable for examination of cells. Side rows of cells are carried 12 in. higher under the transoms, the construction of base of transoms being similar to that of floor.

The bottom of the compartment is of creosoted pine, laid in concrete and covered with a special mixture of non-conducting cement. Wooden partitions are worked longitudinally to separate the rows of cells; the spaces between the cells are filled with asphaltum cement for purposes of rigidity and insulation, and the whole compartment is suitably ventilated by electric fans.

The storage battery consists of sixty Gould elements, with plates of the Planté model, located on each side in twelve rows of five elements. A complete element weighs 1200 lbs. and measures 35·5 by 19 by 17 in., and the weight of the complete battery, including the asphalt employed in its insulation, is about 75,900 lbs.

Each element contains 17 Planté plates. It is calculated that the positive plates should last five years and the negative plates nine years. The installation of these batteries is such that it will allow an inclination of 45° in any direction without danger of spilling the electrolyte. Each element is covered with a cap provided with rubber packing with a central hole, in order to make terminal connections and to permit the examination of the element and the density of the acid.

The following are the general dimensions:—

Over-all dimensions of cell	$35\frac{9}{16}$ by $18\frac{3}{4}$ by $16\frac{5}{16}$ in.
Number of plates in cell	17.

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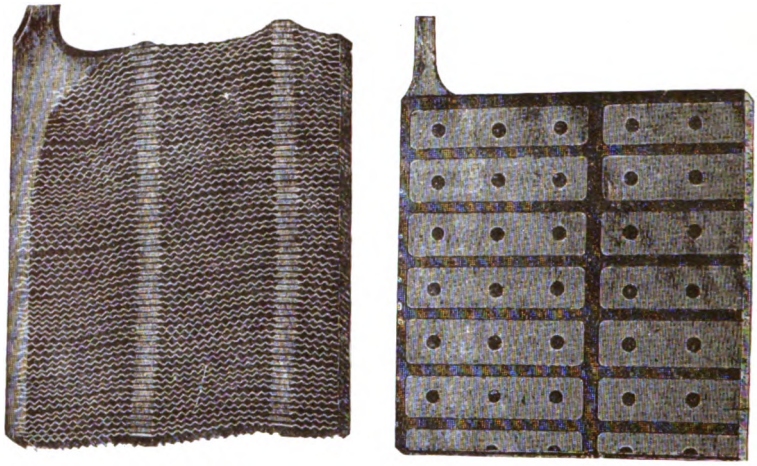

(*a*) Positive. (*b*) Negative.

FIG. 44.—*CELL PLATES OF THE SOCIETÉ METAUX.*

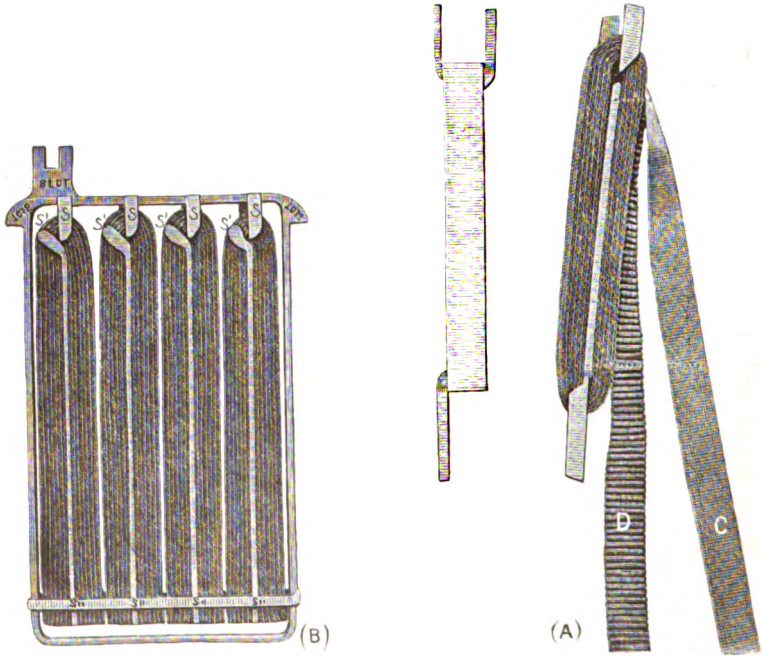

FIG. 45.—*THE SHUTTLE PLATE OF M. BLOT.*

A.—Shuttle. *B*.—Shuttles in position.
C.—Plain Lead Ribbon.
D.—Gimped Lead Ribbon.
F.—Frame.
S S' S'.—Method of fixing shuttles in position.

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	Positive.	Negative.
Projected area of plate .	837 sq. in.	837 sq. in.
Developed area of plate .	8,931 „	10,422 „
Ratio of surface development	10·6	12·4

	8 hours.	5 hours.	3 hours.	1 hour.
Capacity of battery at varying discharge rates in ampère hours	2,240	1,960	1,680	1,120
Electrical horse-power . .	42·5	59	85·5	..

The battery can be discharged at a rate well beyond the capacity of the motors without injury to the plates. The plates are electro-chemically formed, and are contained in cases of antimonious lead, lined with lead. They are supported and insulated from the case by plate glass, and are separated from each other by hard rubber tubes. The top of each cell is provided with an antimonious cover, carrying a rubber gasket, in which is left a centre opening 5 by 5¾ in. for terminal connections and to permit examination of cell for any sulphating that may occur (this usually takes place on the positive plate); also readings of acid density can be made through the opening without any difficulty.

There are at the present time a large variety of electric accumulators in use in the French submarines. The Cely type was installed in some of the early boats, in which the surface of the plates is increased by pouring into the holes of a lead and antimony plate-frame, chloride of melted lead. This prepared plate is placed in dilute sulphuric acid, then a voltaic couple is formed by introducing a zinc cylinder into the exciting liquid; the chloride is thus reduced to a spongy mass. The positive and negative plates in this battery have a fairly long life.

The Société Métaux have supplied some batteries having a different method for building up the positive plate; this is made of ribbons of lead wound round lead stops, which also help to maintain the narrow strips in place and keep the plate in shape—Fig. 44 (*a*). The negative plate is formed of a lead and antimony grid filled up with pastilles, as shown in Fig. 44 (*b*).

This type of cell was fitted in the submarines "Français" and "Algérien." Another accumulator of the Planté type is that of M. Blot, in which a large active surface is given to the plates by

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gimped lead ribbon D, with plain lead ribbon C, being made into a shuttle A (Fig. 45) and fixed into a lead frame with suitable supports S, S', S''; four of these shuttles go to form a plate B.

We constantly hear that a fortune awaits any inventor who can introduce a light, cheap, durable storage battery; but still we live in expectation. Mr. Edison has now produced a battery that is supposed to have some merits over the lead cell, which is generally considered to have very nearly reached its limits of efficiency. The advantages claimed are:

1. Lightness; about one-third per horse-power hour the weight of the lead cell.
2. Cheapness.
3. Less time in charging.
4. Capable of withstanding careless operators.

The general principle of this new cell is the same as the lead type, having the usual plates and an electrolytic liquid; the metals used are nickel and iron oxides with an exciting solution made of potash and water. The action is similar to that of the lead cell. If a current is passed from one plate to the other from an external source, the ions of oxygen are liberated from the iron oxide and are deposited on the nickel plate, producing a higher oxide of nickel when this stored energy is used. The ions of oxygen travel back through he potash solution to the iron oxide plate.

The potash solution is a much nicer electrolyte to deal with than sulphuric acid, as it possesses none of the disagreeable odours, and water is added to the solution should it be necessary. Another advantage of this accumulator is that the plates are not torn down in the same fierce way as those of the lead cells, therefore they should be much more durable. The iron oxides and nickel oxides are mixed with fine graphite; they are then pressed by hydraulic pressure into the long grids shown in the small cell given as an illustration (Plate 83).

Mr. Edison has recently discovered in northern Carolina* rich deposits of cobalt. It is believed this discovery will still further reduce the weight of the electric accumulator, if the plates are constructed on this new process.

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* Also deposits of cobalt have been located in Canada, Wisconsin, Oregon and Kentucky.

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PLATE 83.—*A SMALL EDISON ACCUMULATOR.*

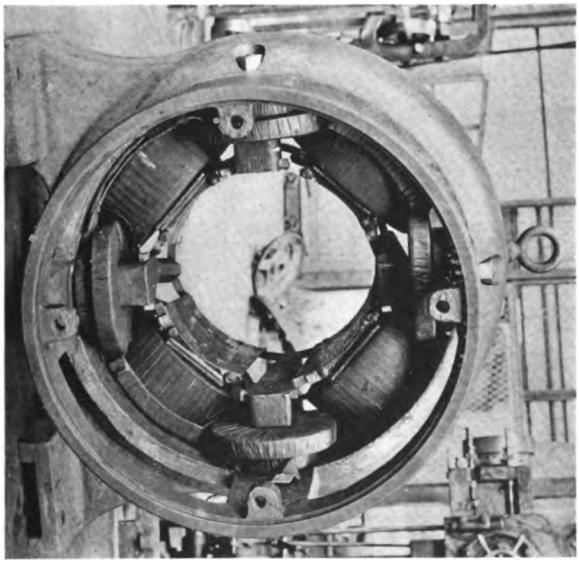

PLATE 84.—*AN INTER-POLAR MOTOR, SHOWING POSITION OF FIELDS.*

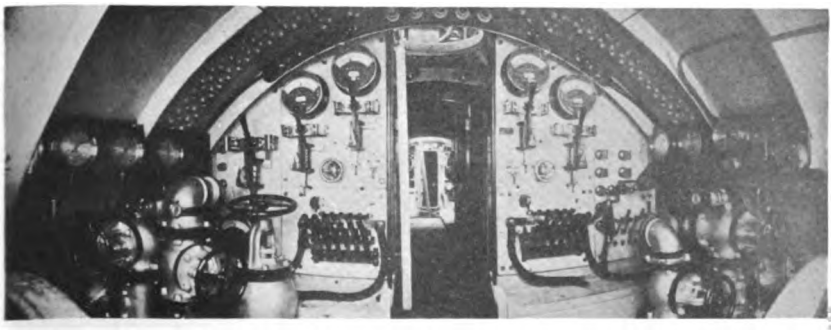

PLATE 85.—*SWITCH-BOARD AS FITTED IN LAKE TYPE SUBMARINES.*

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There are many types of electric storage batteries on the market which it is considered might be suitable for submarine work, but all these are based on the principles already described.

Having briefly considered the system of storing electricity in submarines, we now come to the method of using it.

It is not thought desirable in this book to give a detailed description of the modern electric motor, as these machines are now in such general use as to render it unnecessary, and the author, therefore, would refer his readers to the many text-books on this subject which have been published. It is necessary to state, however, that very special precautions must be taken with the insulating materials used in the construction of the machines; they should be rendered absolutely impervious to moisture, and should be thoroughly well protected against mechanical and other damage. In the modern shunt-wound motor is found an ideal driving power for propulsion when submerged.

To obtain a fair variation of speed, the grouping switch controlling the batteries being worked to maintain a constant supply voltage, a rheostat or shunt-regulating resistance is introduced into the shunt-winding circuit of the motor. By the use of the rheostat the current in the shunt winding of the motor may be lessened and the speed of the motor increased, or the current may be increased with a consequent reduction in speed.

The range of speed by shunt regulation in a good machine can generally be increased to as much as 25 per cent. above the normal. It is not advisable to have too much range of speed by altering the shunt excitation, because a weak shunt current, with consequent high speeds, tends to give what is known as bad "commutation," and excessive sparking at the brushes ensues. This is very much to be avoided in a submarine boat. If more variation of speed is required than can be obtained by the rheostat in the shunt, it is necessary to insert resistances in the armature circuit.

This method is very wasteful; and as the resistance may have to be left in the circuit for some time whilst getting the boat out of harbours, docks, etc., or in close traffic, it must be designed to carry for a considerable period a heavy current, a large amount of material being required and the necessary arrangements made for getting rid of the heat which would be generated.

The question of sparking at the brushes has to be considered in

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such a confined space as a boat, where traces of explosive gases may be in the air. We notice in an ordinary shunt dynamo the line of demarcation between the positive and negative fields varies in position according to the load on the machine, on account of the distortion of the main field by the cross field produced by the current in the armature. Hence the greater the load the more the brushes must be shifted towards the leading pole piece. It will be seen that if the reverse field could be increased in strength proportionately to the armature load, the distorting effect of the latter might be neutralised and a fixed position of the brushes be secured. Several attempts have been made in French submarine boats to effect this by placing small series-wound commutating poles between the shunt poles (Plate 84). Such a system of auxiliary poles has not always been successful in providing the necessary constancy of field in the commutation zone.

These machines, when used as motors, will run sparklessly under three conditions:

1. At constant speed at all loads, like a compound motor.

2. At decreasing speed with increasing load, with consequently a large starting torque.

3. At increasing speed with increasing load.

Few people outside submarine workers have had experience of large tandem motors, *i.e.* two motors on one shaft, as provided in the French boat "Narval." She was the first to be fitted in this manner; and, in spite of the speed regulation of shunt motors being nearly perfect, it was found there was always the tendency for one motor to drive the other as a dynamo. To overcome these fluctuations, which are due to reactions in the armature, a few turns of series winding, arranged in opposition to the shunt winding, gave beneficial results; and this form of compounding has been adopted in some cases where extreme fineness of adjustment is required.

Recently great improvements have been made in brushes and brush holders, and when higher voltages came into use for running various machines the carbon brush was introduced, and it is now practically indispensable. With the moist air, due to condensation, etc., in the boats, it is very necessary that the commutator should receive a certain amount of intelligent attention. The practice in many types of machines is to place the brushes so as to commutate in a line drawn through the centre of magnets. This, however, in

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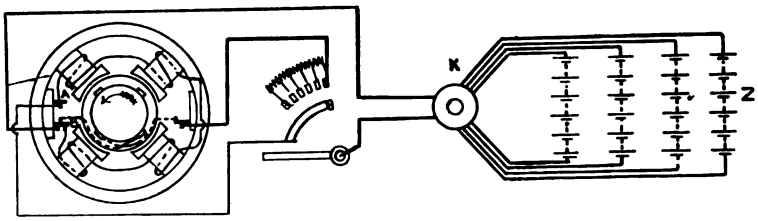

FIG. 46.—*SHUNT-WOUND MOTOR.*

To alter direction of rotation, reverse shunt connections A B.
To run as Dynamo, alter no connections.

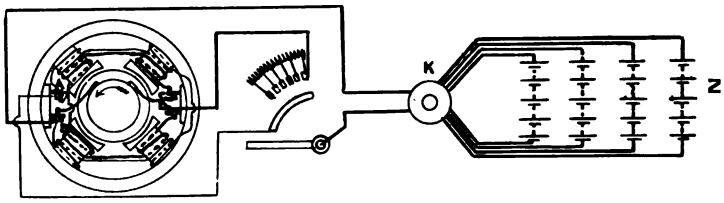

FIG. 47.—*COMPOUND-WOUND MOTOR.*

To alter direction of rotation, reverse shunt connections A B, and series connections C D.
To run as a Dynamo, reverse connections C D.

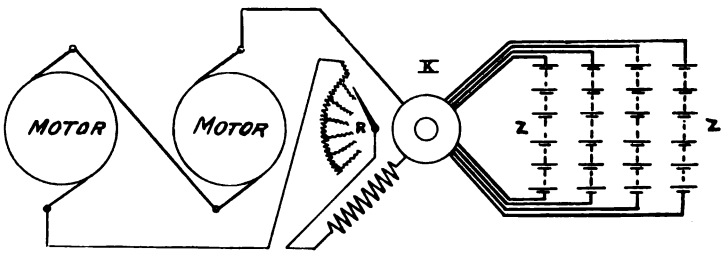

FIG. 48.—*TANDEM MOTORS COUPLED IN SERIES.*

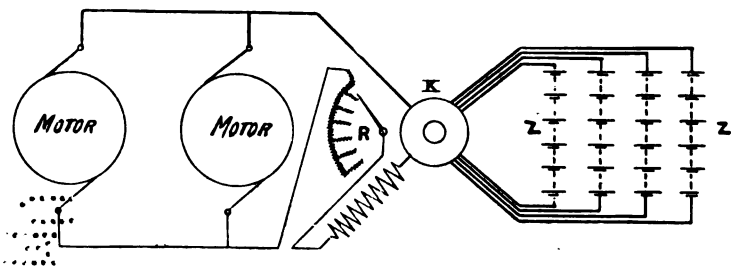

FIG. 49.—*TANDEM MOTORS COUPLED IN PARALLEL.*

In Diagrams K.—Grouping Switch.
R.—Adjustable Rheostat.
Z Z.—Electric Accumulators.

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motors for submarine boats, has to be altered to the middle of the non-sparking position, as the motor has to work ahead as well as astern, and every effort is made to reduce this sparking to a minimum.

The shunt motor run as a dynamo for charging up the electric accumulators is perhaps one of the most perfect examples of a reversible machine. If the motor has electrical energy furnished at its terminals by the accumulators it will produce power, *i.e.* revolve the main shaft and rotate the screw propeller. If, however, the propeller shaft is unclutched, the gas-engine can then be utilised to revolve the motor, which, by altering a few connections, is capable of running as a dynamo for recharging the electric accumulators. The gasolene engine has to drive the motor at a little higher speed than it would run at a given voltage to generate current at that same voltage.

Fig. 46 shows an ordinary shunt motor diagrammatically, with a starting switch and connected to electric accumulators.

Fig. 47 shows a motor compounded for working in tandem, the series coil being wound against the shunt.

Fig. 48 shows tandem motors coupled in series.

Fig. 49 shows the case of tandem motors, that is, two motors on the same shaft, coupled in parallel.

The grouping switch allows 50, 100, 150, 200 volts being obtained according to the size of battery.

It is found by practical experience that shunt-wound motors under load are rather difficult to start; this would be objectionable for submarine-boat work, therefore devices have to be introduced to overcome any delay in getting under way. The shunt winding is a separate circuit of fine wire round the coils of the field magnets; if the current is suddenly switched on the full amount will not flow at once, due to what is known as "impedence." This is always noticeable when a current is made to flow in a wire coiled round a magnet, and may be considered due to the establishment of an electrical field from a zero field.

The armature circuit is separate from the shunt, therefore with a little impedence and low resistance a heavy current will flow if the motor has not had time to get up speed. The heavy current in the armature is scarcely any use as it has little turning movement unless the field magnets are excited. From this it would appear desirable to build up the field first by completing the shunt circuit

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before much current is allowed to the armature and break before stopping. This latter would, however, be dangerous, as, if the field circuit were established and then broken, all the lines of force would instantaneously close and excessive sparking occur, which might break down the insulation of the machine.

Examining Fig. 46, we see how this can be avoided by a suitable starting switch, which provides for the shunt winding being permanently connected to the first step of the starting resistance. This allows a minimum current passing through the armature and gives time for impedence to be got over sufficiently for a fair field to be established before switching on to other stops. These starting switches require careful watching to prevent the current remaining on the resistance too long and thereby generating excessive heat.

A reliable form of starting switch is essential for successful manipulation of electric motors. Such a device must be able to open the motor circuit under all conditions, from full speed speeded up ahead to full speed speeded up astern. No injury to the contacts during the required changes should be possible.

The contacts, which are liable to wear and tear, must be accessible and repairs made easily. A starter suitable for submarine boats ought to have a removable cover to facilitate thorough inspection of most of the parts and for protection of the contact surfaces. With the cover on, the contacts should be totally enclosed to prevent sparks igniting any gas that might be held in suspension in the volume of air within the boat. A large number of points are desirable to allow the various combination of battery power to be made; for instance, when working the boat in confined waters, slow speed, half speed and full speed, ahead or astern, may be required.

For altering from ahead to astern, the motor is stopped and the reversal of the field winding made by a suitable switch. The propeller can then be rotated in the opposite direction.

The nominal E.H.P. of the motor in Holland's design is 70 to 75, number of poles 4, revolutions per minute, about 800; the motor is shunt-wound and will take a load of 500 ampères at 120 volts.

This motor, when clutched into the propeller-shaft, will give a speed of 6·5 to 7 knots when submerged or when boat is in the

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awash condition. It is also used, as previously mentioned, for charging the cells and starting the gas-engine, and is the only motive power for going astern.

In the electrical arrangements of the "Lake" type submarine, a motor is fitted on each shaft and consists of a six-pole shunt-wound Diable type. Clutch gearing connect these motors to the gasolene engine and tail shaft; when running on surface the brushes are lifted off, the commutator and motor runs free, serving as a heavy fly-wheel.

Each machine has an output of 37½ kilowatts at 125 volts and 300 revolutions per minute; normal load 300 ampères, but momentarily 450 ampères can be taken out. The ordinary armature insulation is insufficient, due to dampness in the boat, and extra precautions are taken in varnishing and insulating materials used. The field coils are also extra heavily insulated.

The aim of submarine-boat designers tends towards decreasing the heavy storage battery. Taking the Lake boat "Protector," the weight in accumulators and motors is 89·895 lbs.; this gives a maximum of only 340 E.H.P. hours. The E.H.P.-hour requires a weight of 264·4 lbs. With the gasolene engine, the weight of fuel, tanks, engines, and gasolene equals 28,131 lbs.; this gives 8400 H.P. hours. One gasolene H.P.-hour is given for a weight of 3·55 lbs. These figures are only approximate, and merely intended to show what a saving in weight can be made if the accumulators can be decreased. The switchboard of a "Lake" boat is shown on Plate 85.

The omniscope of the "Protector" is designed to take in air from the top. This would supply the gasolene engines up to the last dive in making an attack on a ship. Every indication shows that great efforts will be made in the future to get rid of the duplication of the source of power, and to make one serve for surface as well as submerged running. The Italian Government have parts of an engine being built in this country for a submarine boat, and it is purposed to draw the air for the combustion motors, when running below the surface, from large air-reservoirs carried inside the boat, on the same plan as in the French boat "Plongeur," in which a large air supply was carried for her propelling machinery. Great difficulties are involved in this proposal to supply a regular air-feed when under water, and it remains to be seen if a satisfactory solution can

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be obtained. The amount of space taken up by the electric storage batteries is seen on examining the "Protector" in the profile plan, Plate 44.

If this could be used for compressed-air storage and a range of 15 to 20 miles ensured at a moderate speed when submerged, a considerable step forward would be made in submarine design. At present the battery largely governs any great advance in the size of these boats.

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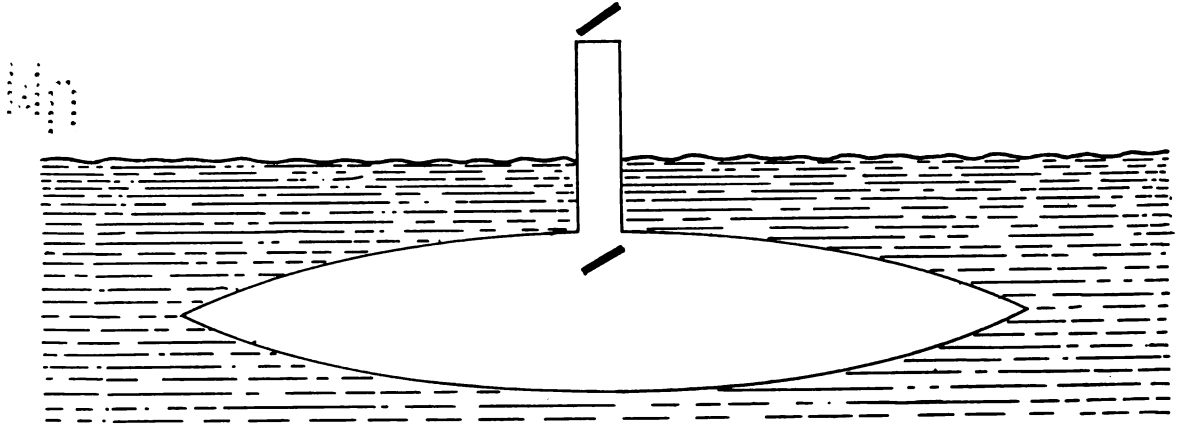

FIG. 50.—*THE FIRST PERISCOPE.*
Invented by M. TELAR VAN ELVEN, of Amsterdam, 1859.

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CHAPTER XIX.

PERISCOPE NAVIGATION.

We have studied the principles involved in trimming a boat for diving—how to steer in vertical and horizontal planes; but this is not all-sufficient, for we require also to obtain a certain degree of safety when submerged navigation is necessary. For a great many years this was limited to the actual distance one could see through the scuttle of a conning-tower, this range in clear water, with the sun shining at a depth of 15 ft., being not more than 10 yards or so. Nature cannot help us at all in this direction, as fishes have poor sight, and in deep lakes where very little light penetrates they are nearly blind; but to guide them in their search for food they have a keen smell and also a well-developed sense of touch. The optical effect of a descent in a submarine strikes one on the first occasion as being peculiar. As the ballast-tanks are filled the boat gradually loses buoyancy, the water comes over the deck, then sprays over the glasses of the conning-tower. If the dive is made when the sun is out the boat appears, when near the surface, to be in a luminous patch, which seems to get smaller as the depth is increased, while, if it is rough water overhead, this luminous patch flickers about and gradually gets smaller and smaller as the submarine goes deeper, until darkness completely envelops the boat. If the sun gets too low very little light penetrates beneath the surface of the water because of the obliquity of the sun's rays. The colour of the water depends on the state of the sky and the nature of the bottom, varying from blue to yellow and finally to a yellowy green. Some instrument is therefore necessary to enable the captain of the submarine to control his direction when submerged, and this, thanks to Bushnell, Fulton, Bauer, and others, can be done with great accuracy by the aid of a compass.

This, however, is not quite enough, as we want to navigate with as much safety as possible, and therefore some means must be found for conveying the reflection of objects on the surface to those working

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the boat below. As far back as 1859 a semi-submarine was designed about which little can be traced except that she was intended for the War of Secession just starting in America. Her designer was M. Telar van Elven of Amsterdam. She was to be used for working with the conning-tower awash, and for protection from gun-fire the upper works were plated. A boiler was used to furnish steam-pressure for an oscillating engine. Further details are unnecessary, as she is only introduced as being the first boat to bring into use a device for seeing at a greater range when shut down and almost wholly submerged. A long tube was erected with a mirror at the top (Fig. 50), placed at an angle of 45° to the vertical, and at the bottom of the tube another mirror was placed, also at an angle of 45°. The tube and the top mirror could be turned, as also could the bottom mirror. This was undoubtedly the embryo periscope which is now in everyday use for submarine navigation. In 1886 Admiral Sir Cooper-Key criticised Mr. Nordenfelt's boat as follows :—

"In our investigations of the boat during the Crimean war we came to the conclusion that it would be perfectly useless, because you cannot see under water sufficiently to guide you to any given object. In Mr. Nordenfelt's boat there is no means of seeing under water; therefore I believe that unless you can approach a vessel with your cupola above water, to see where your enemy is, and the direction and distance you should steer, you will not effect much. You might approach it this way during twilight, or by night, or in a fog, without much difficulty. I doubt whether anyone would go down under water and fire the only implement of destruction he possesses at a vessel that he does not see; but I do think that with the cupola above water, or with the smaller cupola and projecting mirror, it would prove a very formidable means of attack."

During the trials off Landskrona, one of the War Office representatives, Major Clarke,* suggested to Mr. Nordenfelt that a tube with a camera-obscura lens on top would largely overcome the limited vision complained of; but Mr. Nordenfelt did not take to the idea for his boats.

We will take the simplest case first and consider (Fig. 51) the camera lucida. This consists of a four-sided glass prism ABCD. The angle at A is a right angle, and when in use the sides AD, AB

* Now Sir George Sydenham Clarke, G.C.M.G., R.E.

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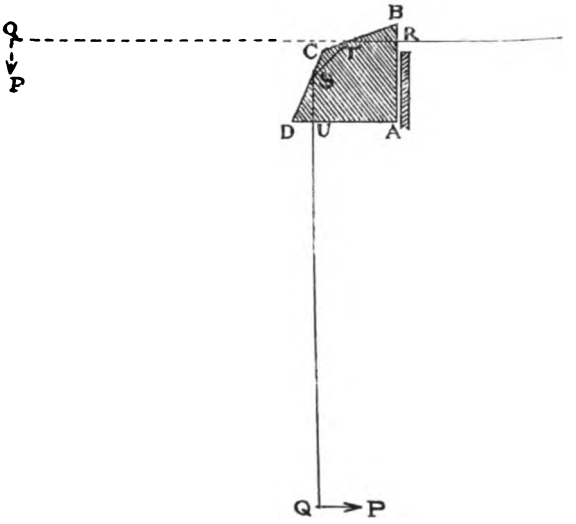

FIG. 51.—*THE CAMERA LUCIDA.*

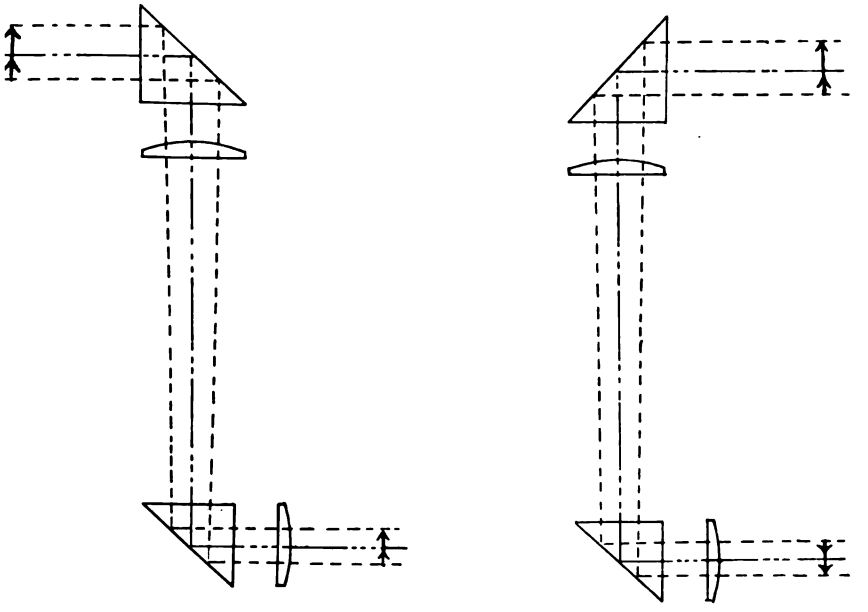

FIG. 52.—*TO SHOW REVERSION OF THE ARROW WHEN TOP PRISM IS TURNED IN AZIMUTH THROUGH* 180 *DEGREES.*

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Naturally the details of the construction and the optical and mechanical arrangements of periscopes are highly confidential. Many pamphlets, chiefly foreign, are written on the subject, and out of one I give a sketch of the combination of lenses believed to be used in an Italian submarine boat to obtain accurate horizontal vision.

The optical elements employed in this erector are shown in Fig. 53 and comprise the total reflecting prism A, the erecting prism B, the object-glass C, the ridge prism D, and the astronomical eye-piece O.

The rays coming from the arrow are reflected downwards by the prism A into the prism B, which effects erection in one direction. After passing the object-glass C, the picture is deflected laterally by the prism D, as Fig. 54 shows. An image of the object is thus presented at E in a position corresponding to the actual one, and is here magnified by the astronomical eye-piece.

The peculiarity of the prism B, of rectangular cross section, is that, on rotation about its longitudinal axis through 180°, the image is rotated through 360°, that is to say, the image turns with twice the angular velocity of the prism.

Thus it is merely necessary to turn the prism B with half the angular velocity of the prism A in order to obtain a picture corresponding to the actual one. For this purpose the prism A is arranged in a casing U provided with teeth at the bottom and rigidly connected with the worm drum H; the latter is mounted with capability of rotation on the casing K, which is screwed over the casing V and provided with a screw-cap G. Turning in the casing V is a tube L, screwed to the top of which is the mount containing the prism B and to the bottom the mount of the object-glass C; the top of the tube L, like the bottom of the casing V, is provided with gear teeth, and in both teeth the double pinion M engages, the ratios of transmission being so selected that the tube L is rotated with half the angular velocity of the frame A and in the same direction.

By turning a worm mounted in the cap G and engaging with the teeth of the drum H, the reflecting prism A, and with it the prism B, is rotated, whereby the characteristic panoramic effect is produced in the field of vision.

The periscope of Captain Darrieus, who had much experience of French submarines, is very ingenious (Fig. 55). It consists of two crystal rings of a triangular cross section which reflect the image to

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FIG. 54.
ERECTOR PRISM.

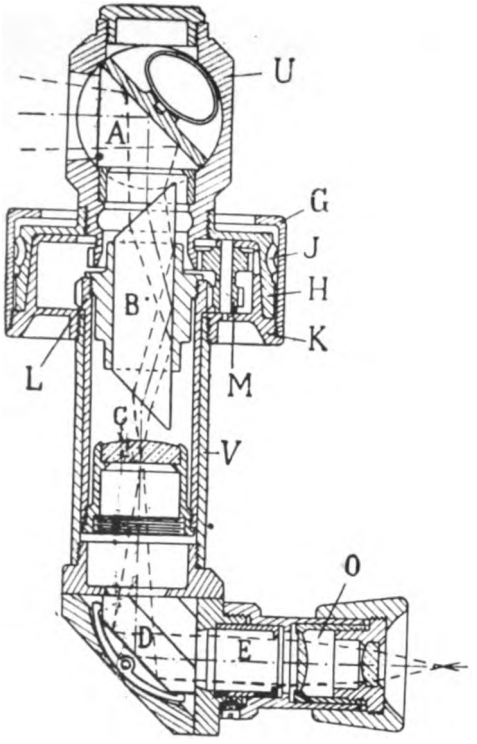

FIG. 53.—*PERISCOPE ERECTOR.*

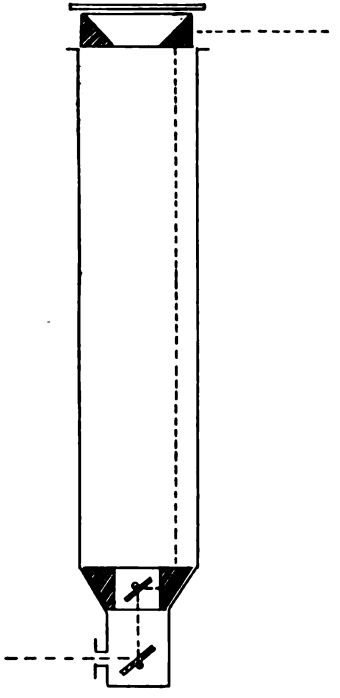

FIG. 55.
PERISCOPE OF COMMANDER DARRIEUS.

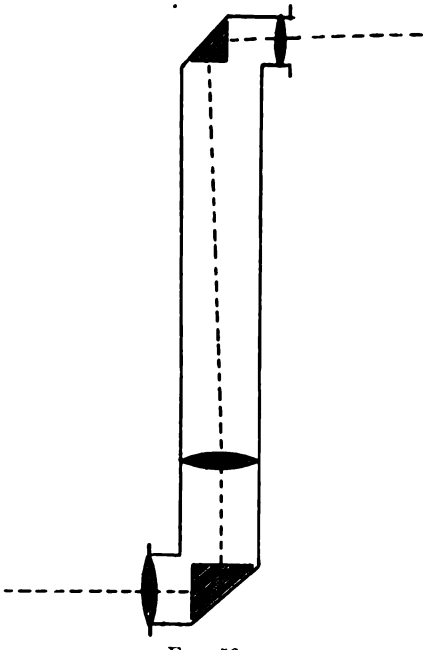

FIG. 56.
PERISCOPE OF M. GARNIER AND M. ROMAZZOTTI.

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two similar crystal rings in the boat. This is received on a small mirror between the lower crystal rings, which reflects on a lower mirror, and so to the eye. The centre mirror can be turned through 90° so as to reflect an object from ahead or astern as necessary, and can be turned in azimuth so as to reflect from any portion of the crystal rings. Diameter is 30 centimetres and the height 3·5 metres.

Another periscope is that of MM. Garnier and Romazzotti (Fig. 56). The front glass of this is a convex lens and allows rays to fall on a right-angled prism; these rays are then collected by another convex lens and fall on a second right-angled prism, which reflects them through a last convex lens and so to the eye. The area of vision is 50° and a suitable mechanism is used for turning the tube round the whole horizon. No erecting device is used in this periscope. Diameter 30 centimetres. Length 3 metres.

From a description of the Lake boat "Protector,"* the following extract is taken:—

"Running with the sighting arrangement (called the omniscope, Plate 87, Fig. 57) out of water, the commanding officer has a scope of vision which takes in nearly the whole horizon, and has no difficulty whatever in steering a straight course. The omniscope has five lenses in its upper end. The four smaller glasses are so placed that, with the instrument normal, one lens looks forward, one aft, and one on each beam Above these is a larger lens of four times the power, the smaller lenses are virtually finders, while the larger is used to give normal vision. The large prism can be oscillated to secure a steady view in a seaway, and can be turned so as to be in the direction of view of any of the four smaller lenses. A graduated vernier upon the main lens gives measurements of certain known heights at certain chosen distances. This instrument is reported to have invariably proved satisfactory. The bearing of a target or object which it is desired to hit is automatically transmitted to the man at the wheel, and when the ship is properly steered the gunner at the torpedo tubes is likewise so advised."

In a heavy sea the periscope is naturally at its worst as the field of vision varies from sky to water and water to sky in conformity with the pitching of the boat. In this sort of weather periscope

* *Journal of American Society of Engineers.*

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navigation is not likely to be used very much. With the high conning-tower the modern submarine is a good sea-boat, and if in action the weather was too bad to use the periscope or look out through the conning-tower, the only thing to do would be to run for shelter.

If the periscope gets covered with spray it can easily be washed off by dipping the upper end under water for washing the lenses, looking through it then is little different from looking through a pane of glass with the rain-drops on it. Plate 86 shows periscope of French submarine "Thon."

The development of these instruments is of the utmost importance to the value of the submarine in war-time and will contribute in no small degree to their efficiency, especially if they are ever fortunate enough to get within torpedo range of an enemy.

The requirements of a successful periscope may be summed up thus:—

1. To project sufficiently above the water, so that the hull and conning-tower leave little or no track in the water when travelling at maximum submerged speed and are completely protected by water.

2. To be able to see all round the horizon when rotating the tube in azimuth. Slow and fast gearing should be provided for training.

3. The arc of vision to be equal to the ordinary human eye—about 50°.

4. The vertical field should allow for slight variations in inclination due to the motion of the boat longitudinally.

5. The object to be magnified slightly, so as to have the true relative size.

6. The orifice in which the periscope fits, and all parts, should stand the same pressure as the hull.

Whilst manœuvring at Portsmouth one of the boats had her periscope trained over the quarter watching the torpedo-boat, when she came very near to having a collision with a small schooner that had just anchored off Stokes Bay. The submarine came up alongside the vessel, and the lieutenant went on board to apologise for causing any alarm, and found the captain very much perturbed; he had been rushing up and down the upper deck, shaking his fist at the pole in the water, and shouting to it to stop coming at him, for

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PLATE 86.—*FRENCH SUBMARINE "THON."*

Tallest Tube is the Periscope.

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nothing else could be seen except a few feet of periscope and some bubbles!

In the official trials of the United States submarine "Adder," during the three-hour submerged run, the conning was done entirely by means of a periscope temporarily rigged through the port forward ventilator. This instrument was fixed in position and had a field in view of but 15° on each bow. For over two hours the "Adder" remained submerged without coming to the surface to take an observation, and during this time her average depth as shown on the gauge was about 11 ft., making the conning-tower about 7½ ft. below the surface. The officers who witnessed these trials stated:

"It is absolutely essential to the efficiency of this type of boat that a properly-designed periscope be built and supplied for conning. A submarine can then remain below the surface for a couple of hours without constantly coming up for observations, thereby of necessity exposing herself to the enemy's fire. When there is the slightest disturbance of the water, vision through the lenses of the conning-tower is very difficult on account of the spray and water thrown on them. With a proper periscope the height of the objective lens above water can be so regulated that there will be little or no annoyance from this cause."

The Naval Trial Board of the "Adder" and "Moccasin" finally recommended:—

"1. Two lengths of observing tube, one to project 8 ft. and the other 18 ft. above the deck of the boat. Recent trials of these boats off Newport have demonstrated that, in a moderate seaway, the boats are controlled with great difficulty at depths less than 9 ft. Thus a long observing tube seems necessary to this type of submarine.

"2. The internal diameter of the tube installed on these boats is about 3 in. The dimensions of their conning-towers prevent a material increase in this diameter. The result is that, even with the shorter (8-ft.) tube, the maximum field of vision without a reduction in size of image is about 1° 48′. This means that without an increase of field by reduction in size of image (as in looking through the wrong end of a telescope) one could not see the whole of the broadside of a 500-ft. battleship at a distance of 2½ miles.

"3. A reduction in size of image has been adopted in these instruments to secure a reasonable extension of field. But, inasmuch as

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the human eye, accustomed as it is to seeing things in what we consider their true size, loses all sense of distance when a reduction or magnification of size is effected, it seems logical to expect that, for a successful estimation of range at least, the commanding officer of a submarine must, in the absence of other means of range-finding, be permitted to observe his target in its true size. The most natural method of increasing the horizontal field of an observing tube is, of course, by rotation of the tube in azimuth; this again requires a conning-tower of sufficient size to permit the observer to follow the eye-piece in its rotation."

In the use of the periscope it is possible, after some little practice, to judge distances with much accuracy. Every seaman knows by intuition the size of various objects in a ship; by a system based on comparisons a high degree of efficiency can be obtained in this direction. The chief thing to remember when using the periscope is that the full force of the tide is acting on the boat. On one occasion whilst "No. 1" submarine was making surface runs up and down the Barrow Docks, when abeam of the four-funnelled cruiser "King Alfred," a sudden swirl, caused by the big ship turning her propellers, sent the boat with great rapidity into the left-hand wall close to the high-level bridge. The motor was reversed for full speed astern, then speeded up, but the eddies prevented her from gathering way, and she struck the wall end-on with great force. People rushed and looked over the high-level bridge to see what the noise was. These boats are splendidly constructed, as only a rivet or two sheared on the superstructure. To this day one can hear Barrow shipyard folk talking with pride of how one of their submarines shook the high-level bridge and only a couple of rivets flew!

This incident has led to the often-quoted taunt that the submarine is blind. Even with the periscope, a boat on one occasion ran into a sea-wall, etc. As it happened in this case, the periscope was not in use, the conning being done from on deck.

However perfect the periscope may become, it has the disadvantage of the field prism becoming slightly obscured by spray, and the tendency of the surface of the prisms and lenses to always become clouded, due to the difference of temperature between the inside and outside of boat. The water in contact with the optical tube usually has the effect of lowering the temperature of the air inside it, and the air within that part of the tube in the interior has its temperature

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PLATE 87.—"*LAKE BOAT*" *RUNNING WITH OMNISCOPE ABOVE THE SURFACE.*

PLATE 88.—"*No. 42*" *TORPEDO BOAT AS SEEN THROUGH PERISCOPE OF "A1" SUBMARINE.*

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raised by the heating effect of the electric light, gasolene engine, if recently worked, etc.

To prevent this film of moisture rendering vision through the periscope imperfect, various methods are employed. For example, the Americans have tried a mixture of half glycerine and half alcohol to form a thin film over the lenses and prisms, then an object should look to the observer as clear as "No. 42" torpedo-boat does on Plate 88.

Mr. Lake has recently constructed a periscope, or omniscope, combining the two following known operations:—

(1) Training a rotatable sighting instrument on a target or object irrespective of the course being pursued by the object under observation.

(2) Instantaneously elevating and lowering the instrument.

Fig. 58 shows in vertical section the conning-tower and part of a submarine boat equipped with a periscope embodying these improvements, the conning-tower being submerged whilst observations are being taken through the periscope, the sighting-tube of which is elevated above the surface of the water. A is a sighting-tube, the upper lenses of which are above the surface of the water. This tube A is provided with the usual lenses, and is of uniform diameter, and is fitted with a rounded or conical cap at the top, the construction being such that the tube will readily pass through the stuffing-box C. This stuffing-box is fitted with packing rings of any well-known construction, which serve to prevent water from penetrating into the interior of the boat. G is a hydraulic cylinder with a pipe g^1 leading to the elevating cylinder B. H is an air-cylinder, the piston of which is connected to the piston of the hydraulic cylinder G by means of a common piston-rod. The air supply is received from an air reservoir H^1, which may be at any convenient part of the boat. The stuffing-box and guide-piece C is provided at its upper end with a flap-valve M, which valve is normally held to its seat by a coil-spring. The boat is running with the observing instrument above the surface.

When the boat is running with the observing instrument above the surface of the water and a hostile vessel is sighted, the instrument can be withdrawn below the surface, to prevent any wake or disturbance betraying the presence of the submarine; by turning the handle controlling the valve F (Fig. 58) to the proper position, this action admits air into the end of the air-cylinder H next to the

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hydraulic-cylinder G, and the hydraulic piston, shown in dotted lines, is caused to travel to the opposite end of the cylinder G, which withdraws the hydraulic fluid from beneath the piston, and tends to create a vacuum below the piston, so that the sighting-tube is consequently withdrawn into the lower position, whereupon the valve M immediately closes and seals the upper end of the guide-piece C. The direction of the enemy having been first ascertained, the submarine can be put on a course to intercept her, still maintaining the same depth of submergence. It is now possible to take instant observations from time to time without exposing anything above the surface except for a brief moment. When it is desired to take an observation, the instrument is first pointed in the direction in which the enemy is known to be. The observer puts his eye to the eye-piece, and turns the handle of the valve F, whereupon a stroke of the air-piston in the cylinder H, acting through the medium of the hydraulic fluid passing through the pipe g^1, shoots the observing instrument above the surface again, and the opening in the tube A is brought opposite the eye-piece, so that vision is secured. A turn of the valve F again withdraws the instrument. From experiments it is found practical to take an observation during the brief interval of one to two seconds.

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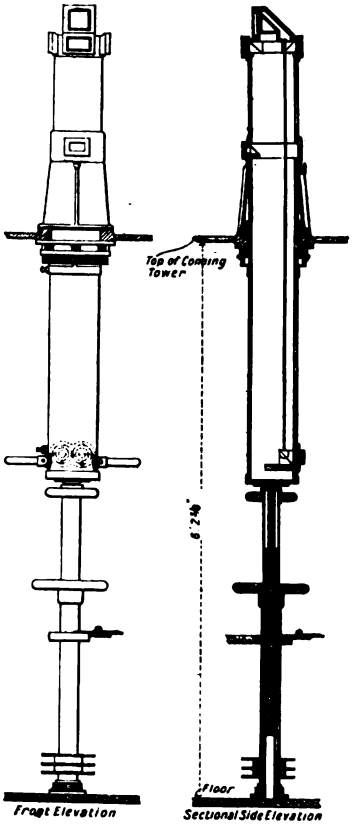

FIG. 57.—*MR. LAKE'S OMNISCOPE.*

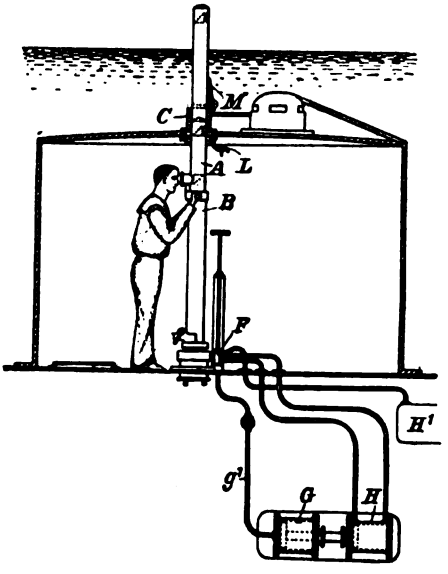

FIG. 58.—*MR. LAKE'S RAISING AND TRAINING OMNISCOPE.*

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CHAPTER XX.

FUMES.*

THE outside air usually consists of nearly one-fifth of the whole part of any volume of oxygen and nearly four-fifths of nitrogen; small traces of carbonic acid, ozone, argon, etc., are also present. Of these constituents, oxygen is the most important, and that on which life depends.

In air that passes through the lungs of the human body, the oxygen is reduced and the carbonic acid increased; that is, the air has given off some of its oxygen to the blood and become itself more carbonised.

Experiments have shown that the amount of carbon dioxide in the outer air is four parts in 10,000; when the air of a submarine exceeds this proportion by more than two parts in 10,000 then the boat becomes stuffy, due to the organic matter and moisture present.

In very large quantities this gas would be fatal, even if breathed for a short time. According to Parkes' *Hygiene*, 50 to 100 per 1000 produces fatal results, and 15 to 20 per 1000 will produce severe headache and serious symptoms if breathed for any length of time.

The following various deteriorating influences to the volume of air inside a submarine have to be studied. It is found an ordinary-sized man breathes out about 6 cubic feet of carbon dioxide in 10 hours, and therefore with a crew of seven or eight men working in a confined space under water, containing in all about 4000 to 5000 cubic ft. of air, it would at first appear that in a very short time the air would become so vitiated as to lead to suffocation. From all the known data on the subject of ventilation, the first crews carrying out breathing experiments of 8, 10, 12 hours' duration, when sealed up in the Holland boats, would have met an early fate. Not so, however; most of these men, if examined, would be found to be perfectly fit,

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* *Service Chemistry*, by V. B. Lewes, F.I.C., F.C.S., has been referred to in writing this chapter.

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and some have now been at the work for years. The reason for this lies in a useful defect that exists in all air-storage systems. We find in actual practice considerable difficulty in storing compressed air in bottles or flasks without some slight leakage. As we have mentioned in studying the early French boat "Le Plongeur," this difficulty was largely *en évidence*, and even in these days, with more perfectly fitted joints, etc., however hard we screw down on to leather or steel washers, slight leakage always occurs. This defect provides a dilution of the air, as the CO_2 increases and allows the crew to remain submerged for several hours in perfect comfort. The slight leakage from the air service is always noticeable, soon after the boat is sealed up and all ventilation closed, by the extra pressure* on the drums of the ears; this is never excessive, but is always felt, particularly when the pressure is entirely released upon the opening of the hatch after coming to the surface. It is evident that the air in a boat can be kept pure in the following ways.

1. The volume may be constantly renewed thus:—
   (*a*) By sucking fans, to draw air into the boat through ventilators fitted through the hull, and exhaust fans for expelling the vitiated air.
   (*b*) By blowing through with the compressed air stored in the boat. This method is too wasteful of air to be often resorted to in practice.

2. By arranging to pass the air over chemical substances or liquids which remove the impurities.

In addition to the impurities of respiration of the crew, there are gases due to the products of combustion of gasolene given off, and traces of carbon monoxide (CO) and carbon dioxide (CO_2) find their way into the boat. As a rule very little of these leak past the piston rings, and what does is usually sucked up into the carburettor again, and goes out with the exhaust gases. However, through defective sealing up of the crank chamber these gases may come into the boat; the carbon monoxide is very poisonous, and quite incapable of supporting life. It is found, if all ventilation is closed for diving, that the air becomes in time naturally foul from the various causes mentioned. In addition, the hydrocarbons,

* This slight pressure is entirely due to the leakage from the reservoirs in which air under pressure is stored. No increase of pressure inside the boat is felt, due to depth of immersion, when working at normal depths.

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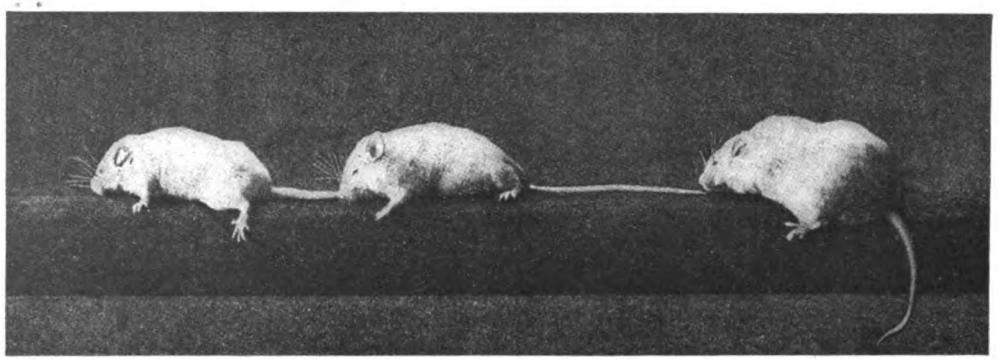

PLATE 89.—*ASPHYXIATED WHITE MICE IN A BRITISH SUBMARINE, AS DEPICTED BY THE AUTHOR OF LA NAVIGATION SOUS-MARINE*, 1906.

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as gasolene, benzoline, etc., give off volatile vapours which are poisonous; so if any free gasolene leaks through a joint it tends, apart from the danger of forming an explosive mixture, to also vitiate the air. At present there is no convenient chemical test for carbon monoxide that can be used in submarines. Many experiments have been undertaken to recognise this gas, as it is a matter of much practical importance, and the value of a good indicator cannot be too much sought after. Indications of the presence of this gas can be obtained by hanging a cage of white mice over the gasolene engine; this is a good practical method, and depends on the fact that in these small animals the blood becomes saturated with carbon monoxide (CO) in a far more rapid manner than in a larger animal or a man.

The amount of carbonic acid produced, and of oxygen absorbed from the air by warm-blooded animals, varies according to the relative area of their external surfaces.

The surface of a normal man is roughly one hundred and sixty times that of an ordinary sized mouse. From practical experiments it has been ascertained that a mouse weighing about 25 grammes produces in one hour at ordinary temperature about 0·25 gramme of CO_2; a man weighing 70 kilos produces in the same time about 40 grammes.

The mouse thus produces in one hour approximately 10 grammes against the man's ½ gramme per kilo. The air then exchanged in the lungs would be in the proportion of 20 to 1, and therefore one may infer that the mouse will absorb carbon monoxide twenty times as rapidly as a man. In practice, the mouse in an atmosphere containing carbon monoxide in a large proportion will soon start to pant and show signs of exhaustion; a man can stand this twenty times as long as the mouse, and it will be some considerable time after the mouse shows symptoms of distress that the crew will become in any way affected. If, however, the mouse suddenly collapses, then a rise to the surface is most advisable, and every endeavour made to blow the boat through quickly.

Mice used as indicators have been employed for many years in coal mines, and their symptoms have always given timely warning of carbon monoxide in poisonous proportions (Plate 89).

It is rather hard on the poor mice to be used for such a purpose, and no doubt they would prefer to be logged officially "D.D." *; then

* Dead.

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surreptitiously smuggled off to a snug home in the north of Ireland as was done by the kind-hearted captain of one of our first submarines.

In French boats the foul air is passed through a caustic soda solution which takes up the CO_2. The air then requires a small addition of oxygen, to supply which a substance named oxylith is sometimes used. This is made up in small tabloids that can be dropped in a glass of water; these are prepared from certain peroxides (sodium, potassium, calcium, etc.) which are very rich in oxygen.

Peroxide of sodium contains . .	20·5	per cent. of oxygen.
„ „ potassium and sodium .	29·09	„ „ „
„ „ potassium . . .	33·80	„ „ „

They yield chemically pure oxygen under the simple action of water. The water saturated with the residue of the reaction contains a considerable quantity of caustic soda in solution.

As a man also consumes seven parts of oxygen per 10,000 in ten hours, a fresh supply may at times be desirable during long submerged runs. Compressed oxygen is sometimes carried for this purpose in a reservoir, but the danger in allowing too much oxygen in the boat is that it over-exhilarates the crew, which is, to say the least, undesirable.

The want of oxygen is not felt up to the extreme limit of tolerance of CO_2. Symptoms due to deficiency of oxygen do not usually appear until the percentage falls to 12 per cent.—that is a reduction of 9 per cent. If, therefore, a portion of the foul air is periodically exhausted from the boat when submerged, it is possible to remain below quite a considerable time. To do this in practice, some of the supply from the air-reservoirs can be used, and the excess pressure allowed to escape out of the boat by the valves provided for that purpose. When the gasolene engine is running for surface awash work, or charging batteries, etc., a large amount of air is required to complete the combustion of the hydrocarbon in the cylinders. This entails several ventilators being fitted to keep up the necessary supply. In rough weather the conning-tower hatch has to be closed, therefore the ventilating tubes are taken as high as possible, to allow of their being kept open in a considerable seaway.

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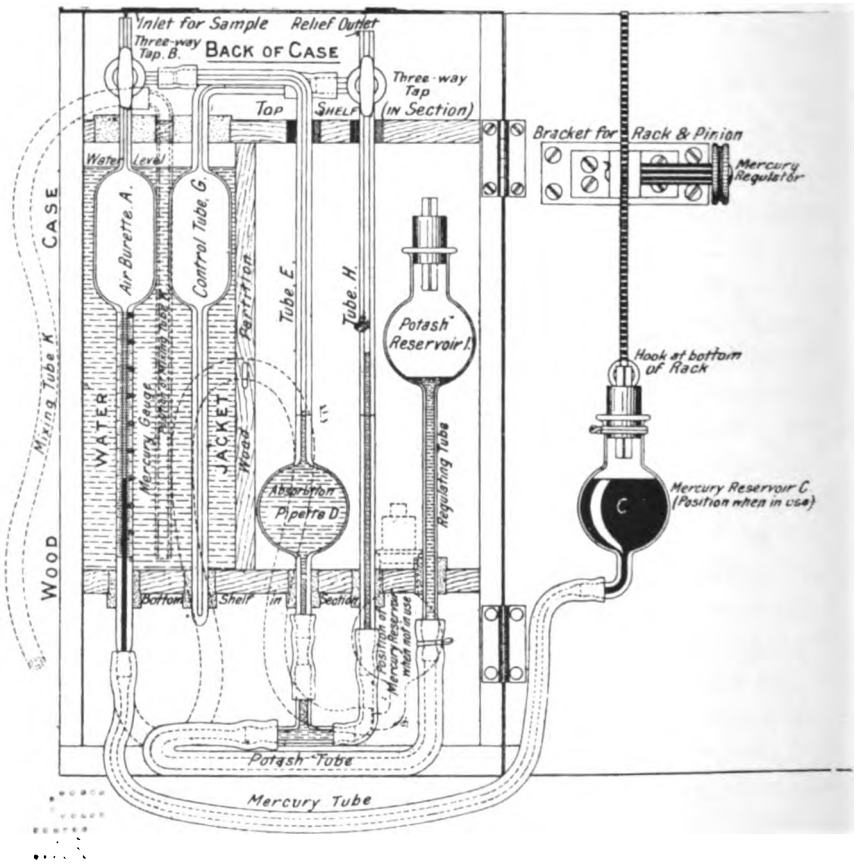

FIG. 59.—*DR. J. S. HALDANE'S APPARATUS FOR DETERMINING AMOUNT OF CARBONIC ACID PER 10,000 VOLUMES OF AIR.*

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Under these conditions the boat is well ventilated. The following appliances are provided in a Holland boat:—

An electric fan is fitted above the gasolene engine and exhausts through the after ventilator. This fan is provided so as to carry off the poisonous gases above the engine; the total prevention of a little leakage is almost impossible. Another fan exhausts the air from just before the engines; this also is exhausted into the after ventilator. Such a system is scarcely adequate, and additional fans in most cases have been fitted to get rid of the foul air that hangs abaft the engine-room partial bulkhead.

In considering the ventilating question, it must be remembered that gasolene fumes are heavier than air; a fan will always draw all the light gas in reach, and though fans may be kept running, it does not follow that the boat is ventilated efficiently. The best criterion of the sufficiency of ventilation is the proportion of carbonic acid in the volume of air in the boat.

This can be readily obtained by one of the many devices for measuring this vitiation now in the market. The instrument usually employed in factories, where good ventilation is insisted upon, is the apparatus of Dr. J. S. Haldane for determining the amount of carbonic acid per 10,000 volumes of air.

To work the instrument, of which a diagram is given (Fig. 59), the following method has to be adopted:—

1. Expel the air from the burette A by opening the three-way tap B to the outside and raising the mercury reservoir C.

2. Lower the mercury reservoir C, so that a sample of the air is drawn in, and the level of the mercury falls to near the mark C, and place the mercury reservoir on the hook of the rack and pinion arrangement F.

3. Open the tap X of the control tube G to the air for a moment by turning the three-way tap to the inside, and then turn the three-way tap so as to connect the control tube G and potash pressure gauge H by giving tap a further quarter turn to left.

4. Give the tap B a quarter turn to left, so as to connect the burette and the potash pipette.

5. Squeeze the rubber tube of the potash reservoir I so as to raise the potash level about 1 in. above the marks, and see that the level of the potash alters sharply and about equally in the two tubes.

6. Blow air through the water jacket.

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7. Raise or lower the potash reservoir I until the potash is exactly at the mark in the tube H.

8. Raise or lower the mercury reservoir by means of the rack and pinion until the potash in E is exactly at the mark.

9. Read off the mercury level on the scale of the burette to two of a division.

10. Raise the mercury so as to drive the air into the potash bulb; then lower it a little, and raise it again twice, so as to wash any carbonic acid in the connecting tubing into the potash bulb.

11. Lower the mercury reservoir so as to return the air to the burette.

12. Blow air through the water jacket.

13. Squeeze the tubing and adjust the two potash levels as before, and then read off the mercury level.

The first reading subtracted from the second gives the result per 10,000 volumes.

14. Turn the two three-way taps so as to close the communication with the potash bulbs.

In addition to these fumes emanating from the products of combustion of gasolene, there are gases given off by the electric accumulators. These are a maximum on first charging, and when overcharging is going on, the electrical energy of the generator simply breaks up the sulphuric acid solution, and free hydrogen is given off in large quantities; at all times, when charging, it is found necessary to ventilate the battery freely. Electric fans sucking the gases bubbling up, and others supplying fresh air, are introduced to keep the battery quite sweet. If a spark occurs during the charging or immediately after, an explosion may be the result; the following incidents serve to illustrate the danger from this cause.

When undergoing some slight repairs, one of the boats at Barrow had a nasty accident from an explosion of battery gases. The battery at the time was being charged and bubbling freely just before closing time, at 5 p.m. and it is generally supposed one of the men struck a match to see how a piece of joiner's work was looking, on completion. This spark ignited the hydrogen gas, and caused a severe explosion, which shattered the battery hatches and seriously injured several of the employés of Messrs. Vickers, Sons and Maxim. These men were got out by the naval crew, foreman and charge hands working on the other boats near at hand. In connection with this

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accident, the first man* to be lowered into the boat received the Bronze Medal of the Order of St. John of Jerusalem, presented by the Prince of Wales, and was promoted to the rank of chief petty officer by the Admiralty. But for the promptness with which these men were got out, the medical evidence stated that loss of life would have occurred in more than one case.

Also we find the American boat "Fulton," belonging to the Holland Company, has not been entirely exempt from accidents. When she was being convoyed from New York to Washington in April 1902, they put into Delaware breakwater. It is supposed a certain amount of hydrogen bubbles plus sulphuric acid gas were given off during the rough weather experienced in her passage. There is a considerable diversity of opinion as to whether the gases evolved under these conditions are of an explosive nature. If hydrogen bubbles stick to the plates and are driven off by the motion, the gas is undoubtedly explosive. In this case a gas explosion occurred which severely bruised several of the occupants of the boat. This was probably due to a spark being caused at the switchboard in operating a switch; a similar explosion occurred in the autumn of the same year† on board the French submarine "Le Français" at Cherbourg. Only one man sustained serious injury in the accident, which happened in the following manner.

A quartermaster, while descending into the vessel, inadvertently turned an electric controlling switch; an explosion at once followed, by which one sailor was badly burned about the face and hands. It appears that after the accumulators had been charged, the boat was not ventilated as it should have been, the result being that the gases generated by this process were ignited by an electric spark produced at the contacts when actuating the switch.

In January of 1905 an explosion of hydrogen gas occurred in a submarine boat at New York Navy yard; this was also, no doubt, due to improper ventilation of the battery after charging the cells. The temporary hatch over the gangway was blown off, and some slight damage caused to the gauge glasses, electric switches, etc., inside the boat.

There is another gas which submarine "No. 4" made us painfully

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* Charles T. Rowe (Torpedo Instructor), petty officer, 1st class.
† 1902.

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aware of in her preliminary dives. Some of the caulking of the main ballast-tank adjoining the battery tanks gave out, and allowed salt water to be forced into the accumulators every time the tanks were blown.

This caused chlorine gas to evolve as soon as the cells became saturated, and on being discharged when working the boat ahead or astern larger volumes were given off; the action is usually supposed to be that the chloride of sodium in the salt water attacks the peroxide of lead in the positive plate in presence of sulphuric acid, forms sulphate of lead, and liberates chlorine. This is a yellowish-green gas which is, volume for volume, 35·5 times heavier than hydrogen. Air containing 5 per cent. will prove fatal to animals if breathed for any length of time; when inhaled in even minute traces great irritation of the mucous lining of the throat and lungs is caused; this produces a short irritating cough which is most unpleasant and lasts for a considerable time.

In recalling the lamentable accident to "A 8," when manœuvring outside the Plymouth breakwater, the evidence stated that the water entering flooded the electric accumulators before the conning-tower hatch was forced down by the incumbent water and subsequently closed by one of the crew. The salt water being a conductor, the battery discharged freely, and in so doing evolved chlorine; this mercifully rendered the imprisoned men in a short time unconscious.

The salt water, if splashed on to the armature of a pump motor, which the evidence showed had been started, would cause sparks, and cause the explosion of the gases that was noticed one hour and forty minutes after her disappearance from the surface.

In confirmation of the presence of chlorine and other gases on an electric storage battery being saturated with salt water, an experiment was carried out by order of the Admiralty in actually flooding the battery tank of one of the small Holland boats at Portsmouth, the object being to ascertain what gases were given off and their probable effect on the crew, and also as to whether the electric lights would remain burning and the power be available to work the pumps. This showed that considerable quantities of chlorine gas were given off from the batteries. Within ten minutes of the flooding of the battery, chlorine was coming off freely, and although the boat experimented with was open and ventilated, Captain Bacon could not

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stay down for more than fifteen minutes, and that right under the fore hatch. In a closed-up boat the effect would be much stronger, and there could be little doubt that, although the men in the "A 8" may have been actually living at the time of the explosion, they had been incapacitated and insensible for a considerable time. That alone fully accounted for the small amount of work done in the boat to raise her, as the electric light would have burned for several hours, and it was found that the hand pumps had not been used. There would also have been ample power available, when the submarine was flooded, to work both the electric pumps. The explosion was most probably caused by oxygen and hydrogen being evolved by the battery discharging under water. Considerable volumes of this gas had generated and must have been present. It was doubtful if petrol had had anything to do with it, but slight traces may have floated on the surface when the water flooded all the connections; this would soon vaporise and form an explosive mixture with the other gases.

However, most of these accidents are preventible, and with proper precautions should not occur. Many Holland boats have the following arrangements for ventilating the battery tanks:—

A ¼-H.P. motor in the space between the tanks, against the hull, and air is exhausted at the top of boat above the after battery tank by a ⅓-H.P. motor and blower. The fresh air is drawn through the conning-tower hatch, ventilators, etc., and the two exhaust motors draw the hydrogen gas from the battery tank and discharge it outside the boat.

Some interesting endurance trials have been undertaken at various times; for instance, in June 1901 the French submarine "Narval" was submerged for a twelve-hour test; the crew on this occasion suffered badly, due to the gases given off from the electric accumulators, which were not in a very satisfactory condition. The air became saturated with sulphuric acid fumes, and the crew had considerable difficulty in breathing. After examining the crew the medical conclusion was that in the then condition of the boats twelve hours was the outside limit for efficient work under water.

Considerable advances have been made since this experiment, as in 1905 we received interesting news from Bizerta that the French submarine "Korrigan" carried out the same test as the "Narval" and remained under water from 6 a.m. to 6 p.m. The crew suffered

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no ill effects from their long confinement, and the gear on board the boat worked most satisfactorily.

A similar trial was made in 1905 by the "Fulton," which remained at the bottom of Narragansett Bay, U.S.A. Starting at 11.15 p.m., all communication with the shore was cut off and the conning-tower hatch closed, the kingstons were at once opened, and the boat gradually submerged; first the main ballast was filled, then auxiliary ballast, and finally buoyancy tank, which destroyed all buoyancy. The boat was taken down 7 fathoms, with a crew of nine officers and men, who kept the boat under water until 11.30 the following forenoon. This test for habitability was quite satisfactory, and the men came up fairly fresh.

The air stored in the reservoirs was not drawn upon until the close of the trial, and then only to ascertain if all the gear was working correctly. Some of the published accounts of the trial record that this is the two-thousandth dip Captain Cable, the submarine expert, has made, which speaks volumes for the safety of the Holland submarine boat when in capable hands. Some enthusiasts count a dive every time they close the conning-tower hatch. The American captain, however, does not come under this category, and the number of dives mentioned is probably quite authentic.

In dealing with the unfortunate accident to "A 5" at Queenstown, at the beginning of 1905, we have again to call attention to the fact that gasolene itself has no explosive properties. It is the vapour of gasolene mixed with a certain proportion of air that forms an explosive mixture which in a confined space is exceedingly dangerous, and should a spark from a switch, motor brush or match occur, a disaster is certain to be the consequence.

We have now had three explosions connected with this fuel in the British Navy which are worth investigating in brief. The first occurred in March 1903, as "No. 2" submarine was proceeding up Portsmouth harbour on completion of manœuvres in the Solent; when off the north corner an explosion was heard, and the boat appeared to the ships alongside the jetties to be in difficulties. This was due to some free gasolene finding its way into the after-part of the boat from a leaky joint; an explosive mixture was formed, and as this vapour is heavier than air, and always tends to remain low down in the boat, whilst turning an electric switch the explosion occurred,

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burning some of the crew badly. Fortunately the captain* of the boat was one of the "Pioneer" crew, and knew at once what had happened, went below and pluckily got the injured men on deck into the "Hannibal's" picquet boat, which was smartly brought to the help of the disabled submarine by an officer who was fortunately an eye-witness of the occurrence. The injured men were taken on board the "Hannibal" and, after medical treatment, were removed to the Naval Hospital, Haslar. This commendable promptitude prevented any casualties, and all the men soon recovered from their mishap.

The second explosion was singular and only indirectly connected with the submarines. The boats whilst in dry dock at Portsmouth had their gasolene tanks flushed out, and some of the fluid appears to have floated on the surface of the water and got into the well of the pumping-station. A dockyard man, descending with a naked light to clear an obstruction, caused ignition of the gasolene vapour, by which he was badly burnt.

The third accident was in "A 5," the details of which no doubt may be remembered by many as being due to a leaky gasolene pump, which allowed free gasolene to be present in the boat in some quantity. This vaporised quickly, and with the air in the boat formed an explosive mixture. To clear this from the boat the electric motor was in the act of being started to turn the gasolene engine, to suck the foul air from the inside, when the explosion occurred.

The official inquiry, opened at Haulbowline, was conducted by Captain R. H. S. Bacon, Naval Assistant to the First Sea Lord of the Admiralty, and Dr. Boverton Redwood, adviser to the Home Office on petroleum oils.

After all the evidence had been taken, Dr. Redwood made a statement, in the course of which he said that, from the evidence given and an inspection he had made of the submarine boat, he had come to the conclusion that if there had not been a lamentable disregard of one of the most important regulations the explosion would not, and could not, have occurred. He considered the existing regulations were amply sufficient to ensure the safe working of the petrol installation, and he could not suggest any improvement in them. No better proof of their sufficiency could be desired than the fact that

* Lieutenant B—— E——.

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during the past two and a half years the submarine boats in the British Navy had collectively run under petrol motor power between 16,000 and 20,000 miles without previous accident, attended by loss of life, due to use of petrol. "In this connection," he added, "I should like to be permitted to add that in my judgment the recent disaster furnishes no ground for apprehension as to the safety of such submarine vessels, and that, on the contrary, the result of this enquiry should, I consider, tend to give increased confidence to those who are called upon to serve in them."

Captain Bacon then delivered his finding. He observed that there had been a strong smell of petrol in the boat. One man was giddy from the smell of petrol, and had gone forward under the fore-hatch for fresh air. In spite of this fact the motors were deliberately started to revolve the engine to exhaust the vapour.

In conclusion, he said: "I find that the explosion in 'A 5' submarine was caused by the presence in the boat of petrol vapour from a leak of the liquid petrol at a badly-packed gland of the petrol pump, and that the explosive mixture formed was ignited by sparks from the main motor brushes, caused by attempting to move the motors electrically with a view to revolving the engine; and further, that such a use of the motor was a flagrant violation of the regulations laid down. Very few words will suffice to deal with the second explosion. The leak of the gland of the petrol pump would supply the petrol vapour and the burning canvas the means of ignition. When the two came into contact a second explosion must result. In conclusion, I must express my appreciation of the attempts made by the officers and men of the 'Hazard' to recover the injured men from the boat, in face of the poisonous fumes, at the risk of their lives from subsequent explosion. For thirty men out of so small a ship's company to volunteer to enter the boat, which was practically on fire, with seven tons of petrol in her tanks, after an explosion had occurred, is a fact of which I consider the Navy may be proud."

These accidents forcibly illustrate the necessity of extreme care on the part of the operators in handling this fuel, and also remind us that a scheme of intelligent co-operation for the general safety should exist in each submarine boat, as it is generally believed, in connection with the above accident, that the lieutenant in charge of "A 5" was overcome by the fumes in the interior, and one of his crew, with

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the very best intentions, gave the order to start the electric motor for ventilating purposes.

By practical tests and the gradual elimination of weaknesses, with more experience in petrol and heavy oils for internal-combustion motors, we shall no doubt overcome the initial difficulties that cannot be dissociated from the development of an efficient engine for propulsion of submarine boats. Many scientists, since the Courrières mine disaster, are making every effort to perfect a suitable apparatus for the ready detection of fire-damp. If an instrument can be produced that will readily indicate the presence of dangerous gases, none will welcome it more than those engaged in submarine work.

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CHAPTER XXI.

THE EVOLUTION OF THE SUBMARINE MINE.

As far back as the siege of Antwerp, in 1585, the Dutch employed what they called explosion vessels, which burst when they approached an enemy's ship. Each of these vessels was fitted with a clockwork mechanism which set a matchlock arrangement in action, and the destructive effect depended on the accurate timing of the mechanism. These weapons were so successful that some 800 Spaniards lost their lives thereby.

The English are generally believed to have used floating petards at the siege of Rochelle in 1628, but these did little or no damage.

These explosives were of the surface variety, which are quite distinct from the purely under-water weapons. To form a definite opinion on this latter type it is necessary to once more refer to Bushnell, the American, who actually invented this form of attack, the development of which has produced such startling results in modern naval wars. In describing his devices the inventor wrote: "To show that powder could be made to explode under water, I first demonstrated before some noted personages in Connecticut, U.S.A., with 2 ounces of gunpowder placed 4 ft. under water, and then by using 2 lbs. of gunpowder placed in a wooden bottle under a hogshead, with a 2-inch plank between the hogshead and the powder. The hogshead was loaded with stones as deep as it could swim. A wooden pipe, descending through the lower head of the hogshead and through the plank into the powder in the bottle, was primed with powder. A match put to the priming exploded the powder with great effect, splintering the wood plank, demolishing the hogshead, and casting the ruins of the hogshead, stones, and a column of water many feet in the air." *

Attention was drawn in an early chapter to the indifferent manner

* Extract taken from *Life of Bushnell.*

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in which Bushnell was supported in his attempt to perfect a submarine boat. This led to his great talent being devoted exclusively to the further development of methods for attacking a ship in her most vulnerable part—the portion below the water-line—by means of explosives. The practical success of these efforts caused much consternation to the Commander-in-chief of the British fleet operating against the American coast-line in 1777.

So much had explosive magazines begun to be feared that general orders were issued to the ships to fire on everything drifting that was of a suspicious nature.

In a paper read before the American Philosophical Society on June 8, 1798, Bushnell relates: "In the year 1777 I made an attempt from a whale-boat against the 'Cerberus,' frigate (British, thirty-two guns, Captain Sir Jacob Wheate, Bart.), then lying at anchor between Connecticut River and New London, by throwing a machine against her side by means of a line. The machine was loaded with powder, to be exploded by a gun-lock, which was to be unpinioned by an apparatus to be turned by being brought alongside of the frigate. This machine fell in with a schooner at anchor astern of the frigate, and concealed from my sight. By some means or other it was fired, and demolished the schooner and three men, and blew the only one left alive overboard, who was taken up very much hurt.

"After this I fixed several kegs under water charged with powder, to explode upon touching anything as they floated with the tide. I let them afloat in the Delaware, above the English shipping, at Philadelphia in December 1777. I was unacquainted with the river, and obliged to depend on a gentleman unacquainted with that part, as I afterwards found. We went as near the shipping as he durst venture. I believe the darkness of the night greatly deceived him, as it did me. We set them adrift to fall with the ebb upon the shipping. Had we been within 60 rods I believe they must have fallen in with them immediately, as I designed; but, as I afterwards found, they were set adrift much too far distant, and did not arrive until after being detained for some time by frost. They advanced in the daytime under great disadvantages, as the British, fearing the making of ice, had warped their ships into the wharves and so escaped much of the intended mischief."

These "kegs" could not be seen, but the buoys that supported them were easily discernible on the water. One of them blew up a

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boat with several persons in it who imprudently handled the explosive too freely, and thus gave the British that alarm which brought on the "Battle of the Kegs," a nickname given in sarcasm to an extra heavy fusillade on these then called infernal machines, coupled with a lining of the wharves at Philadelphia with soldiers, etc., all in readiness for repulsing an attack from the invisible enemy.

Some of the explosive magazines were fitted with an ordinary gun-lock and hammer, which fired by a spring on coming into contact with any obstacle, others were fired by chemical fuses, and on tethering these magazines in pairs a much better chance of success was ensured. When the surface line fouled the ship's cable, the tide swept the machine against her side; the jar was sufficient to ensure explosion, but, owing to the great vigilance displayed by the English, these drifting torpedoes were not very successful, and no great damage was done to their ships.

Some years later the American inventor, Robert Fulton, from purely philanthropic motives, followed up the experiments of Bushnell on almost identical lines, and, as we have seen, the submarine boat was the outcome of his efforts to obtain success with explosive magazines for acting on the under-water portion of a ship.

During Fulton's time the French word "torpille" began to be used in connection with submarine explosive charges, and in this country the name torpedo was subsequently adopted. This term torpedo is derived from the electric rays, family *Torpedinidæ*. In common with the electric eel, the members of this family are characterised by their power of communicating galvanic shocks; the organs from which this power is derived taking the form of hexagonal prisms placed vertically, situated on each side of the front of the dise between the head and pectoral fins. The electric organs are subdivided into a series of cells by a number of delicate transverse partitions between which a clear jelly-like substance is formed. The electric charge generated in these cells, when the circuit is completed by touching any two points, possesses the usual properties, such as emitting a spark, deflecting a needle, etc. These fish are frequently spoken of as torpedoes, and are found in many estuaries of rivers, such as the Tay, etc.

The provision of the electric organs appear to be given to this kind of fish for the purpose of stunning their prey, and also for use

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FIG. 60.—*DEMOLITION OF THE BRIG "DOROTHY" OFF WALMER BY AN EXPLOSIVE CHARGE IN PRESENCE OF WILLIAM PITT*, 1805.

As illustrated in the Life of Robert Fulton.

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in self-protection, as large specimens are reputed to be capable of disabling a man.

To fully demonstrate the power of an explosive under water a small "shallop"* was placed at Fulton's disposal by order of the French Commission—who were then investigating the merits of this new form of weapon—for use in attacking the under-water portion of hostile ships. She was anchored off Brest, and a torpedo was towed against her, with a most satisfactory result, the force of the explosion being sufficient to sink the ship in a very short time. This success was fully recognised at the time; but such a mode of fighting did not appeal to the chivalry of the French naval officers; consequently Fulton and his schemes were not encouraged, and after some few experiments on the Seine in connection with steam propulsion, the American saw that his inventions were to a certain extent discredited in France.

Notwithstanding such a negative appreciation of his efforts, Fulton determined to use his utmost endeavours to induce some great maritime Power to take up these weapons for annihilating navies. With this project in view he crossed to England and laid many schemes before the British Admiralty. In this country a few supporters were found amongst the authorities; but, generally speaking, these innovations were received with disfavour and much adverse criticism.

One invention produced at this time by Fulton was an explosive magazine called a catamaran. This was an oblong wooden vessel, 21 ft. long and 3½ ft. wide, with wedge-shaped ends, covered inside with lead and on top by a thick plank, the whole well caulked and covered with canvas and run over with pitch. The explosive charge consisted of forty barrels of powder placed in the interior of the machine; on withdrawing a safety-pin a clockwork mechanism revolved for a period of about ten minutes, then a gun-lock hammer was released and hit a percussion-cap; the flash thus produced caused instantaneous explosion of the magazine.

An expedition was fitted out in October 1804, under Lord Keith, for operations against the French fleet off Boulogne. The catamarans used in this attack were fitted in pairs and set drifting with the tide; just before release the safety-pins were withdrawn, and

* Schooner.

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we read that the men who pulled them out received some substantial reward, plainly showing overmuch confidence was not placed in these weapons. Several exploded but did little harm, as they were too near the surface, and the columns of water caused by the explosion went harmlessly up the steep stoutly-built sides of the French ships. So confident were those in charge of the expedition that no attempt was made to keep this attack secret, and it was openly talked about. The French protested very strongly against the use of these infernal machines, and described them as a most underhand form of attack, and discreditable to all the laws of chivalry. In order to further prove to those in authority the success of his explosive magazines on a ship, Fulton blew up the brig "Dorothy" off Walmer in 1805. In this experiment a carcass of 175 lbs. of powder was used. The explosion occurred fifteen minutes after withdrawing the safety-pegs, and caused the brig to break clean in two (Fig. 60).

These experiments failed to produce the impression desired. Consequently Fulton returned to America with the full determination to still further advance his ambition for demolishing navies by explosives. In 1810 a Committee, constituted of United States naval officers, was appointed to investigate this enthusiast's latest inventions, particularly that of a harpoon torpedo (Fig. 61). The harpoon was intended to be discharged from a special type of musket, capable of being carried in an ordinary boat. The sharp point of the harpoon could penetrate the hull of almost any ship then afloat. When this was fixed into the side of an enemy the tide carried the float D towards her; this supported the torpedo B, which was swept into contact with her bottom, the impact being sufficient to release the spring gun-lock and so explode the charge. The safety line K cocked the lock on the discharge of the harpoon, the powder was carried in the vessel B, and the portion C was made of cork so as to assist the float D in supporting the heavy magazine of gunpowder.

The inventor proposed to fit out a large number of boats armed with this weapon for the protection of the principal ports of the United States.

To try their efficacy the Committee carried out experiments with the U.S. frigate "Argus." The defence of this ship was placed in the hands of Commodore Rodgers, who arranged to surround the vessel with booms, swinging spars armed with scythes, nets to touch the ground, etc. This elaborate form of protection made it quite

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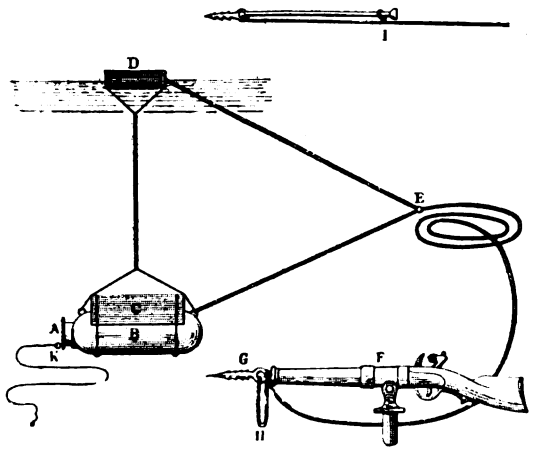

FIG. 61.—*FULTON'S HARPOON TORPEDO.*

A.—Firing Lock.
B.—Case for carrying Explosive.
C.—Cork Slabs.
D.—Float for supporting the Torpedo.
E. I. H.—Shows method of attachment.
G.—Harpoon.
F.—Musket.
K.—Safety Line.

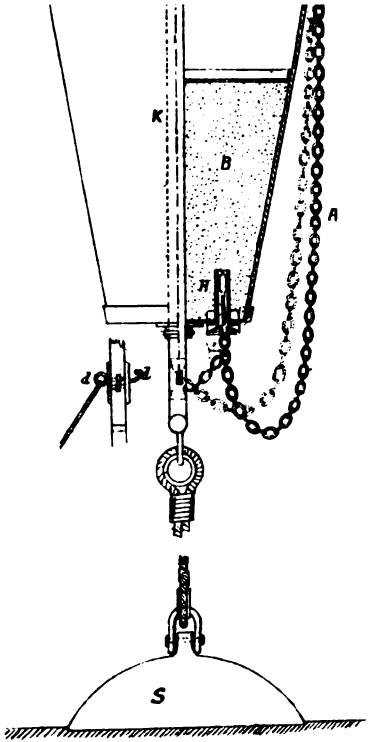

FIG. 63.
SINGER'S MECHANICAL MINE.

A.—Attachment Chains.
B.—Lower part of Mine Case filled with Powder.
d.—Safety Pin.
H.—Friction Tube.
S.—Mooring Sinker.
W.—Weight for Firing Tube.

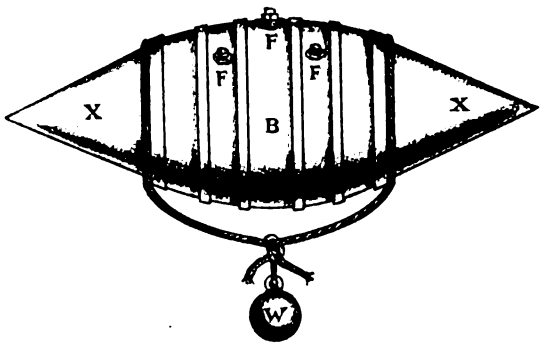

FIG. 62.—*THE BARREL TORPEDO.*

F.—Chemical Fuzes.
X.—Wooden Conical Ends.
B.—Barrel filled with Powder.
W.—Weight for keeping Torpedo upright.

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impossible for the frigate to have been fought efficiently, had it been necessary to clear her for action.

Fulton modestly acknowledged that the ingenuity of the commodore in defending his vessel was greater than his in attacking it, but at the same time argued that "a system which, then only in its infancy, compelled a hostile vessel to guard herself by such extraordinary means could not fail of becoming a most important factor in war."

In writing on the defence of the "Argus" the inventor further remarked: "The embarrassments which Commodore Rodgers threw in my way was no defeat of torpedoes, it was only a defeat of the mode I then practised. As a brick wall 1 ft. thick will stop a musket bullet but not a 24-lb. shot, as well might it be said that defeating the musket bullet proved gunpowder not so good as bows and arrows."* With this parting sarcasm at the expense of the members of the Committee, Fulton abandoned torpedo work and turned his attention to the furtherance of some embryo experiments first undertaken by him in Paris in connection with marine steam propulsion.

In the application of this power as a propelling agent for vessels, the American obtained considerable success; but when it came to a question of patenting his devices, others were in the field, and some considerable amount of litigation followed, which is probably dealt with in works on the early history of the steam-engine.

During the Crimean war of 1854–6 the Russians used submarine mines against the allied forces, principally in the defence of the harbours of Sebastopol, Sveaborg, and Cronstadt. These were invented by M. Jacobi, and were of the mechanical type, containing 25 lbs. of gunpowder; a chemical fuse was provided for obtaining ignition, this consisted of a glass tube containing sulphuric acid, which, on being shattered, allowed the liquid to fall on chlorate of potash. On contact taking place, heat and flame were evolved, due to chemical change, and by this means the explosion of the whole charge was ensured. One mine was exploded under H.M.S. "Merlin," but, owing to the small amount of power used, beyond a severe shaking, no damage was done.

Electrical mines were also utilised to a slight extent, but neither

* *Submarine Warfare*, Barnes, page 230.

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these nor the mechanical type appear to have done much damage. On the conclusion of hostilities the Allies found many mechanical mines with the safety caps, for protecting the chemical fuse whilst laying, left on; this would afford some explanation of their want of success.

In the American Civil War submarine mines were extensively used; the primary cause of this recognition of their value was due to the large number of ships placed in commission by the Federals for blockade work and attacking the forts of the Confederates. The latter had few ships with which to meet this numerical superiority, and therefore developed the mine as being the most suitable weapon for attacking the vulnerable under-water portion of the heavy armoured monitors and other ships operating against them. The Federals retaliated with similar weapons, which led in no small way to the continuation of this long and desperate struggle. A few of the incidents bear a short repetition.

In December 1862 Admiral Porter ordered the senior officer in charge of the Federal gunboats to enter the River Zazoo and get possession of as much of it as possible to enable the troops to attack Vicksburg by that way. In reconnoitring the river many torpedoes were observed, therefore two light-draft gunboats were sent on in advance with orders to raise or sink with gun-fire any torpedoes that were seen. These vessels were followed by two of heavier type. One of the former commenced firing at a floating torpedo and was instantly supported by a heavier boat named the "Cairo," * which thought sharp-shooters were being engaged on the bank of the river. In doing so the latter crossed two torpedoes. Loud explosions occurred in quick succession, one under the bow and the other under the stern. The damaged one caused the gunboat to sink in 6 fathoms in twelve minutes.

These torpedoes were merely demi-johns fitted with powder and ignited by a common friction primer rigidly secured inside. To the primer was fastened a wire passing through a water-tight bung made of gutta-percha with a plaster of paris joint.

The first idea was to explode them by pulling a wire from the shore, but subsequently they were more elaborately fitted by a Confederate officer in pairs and moored 20 ft. apart, the wire leading from the friction tube of one mine to a similar device in the other.

* Mahan, *The Gulf and the Inland Waters.*

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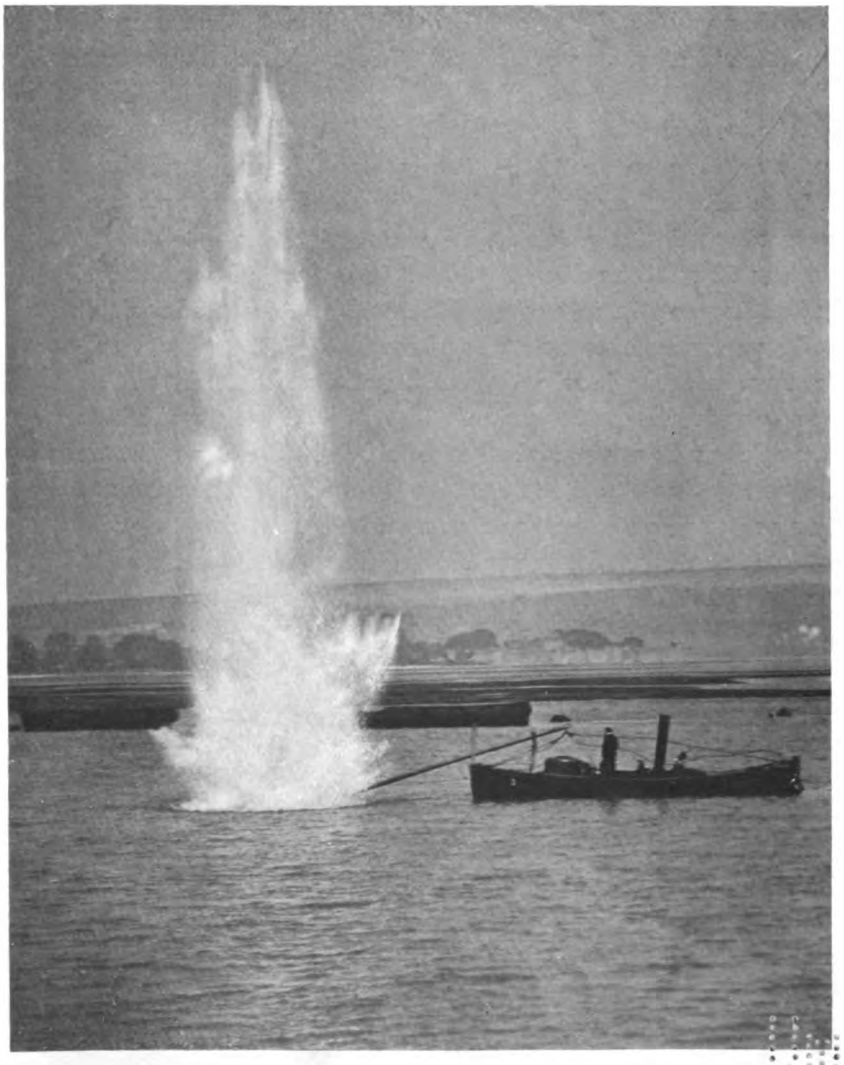

PLATE 90.—*EXPLOSION OF A SPAR TORPEDO CHARGE, ABOUT 20 LBS. OF GUN COTTON.*

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Captain Mahan writes in connection with this incident: "Torpedoes had hardly yet come to be looked upon as a respectable mode of warfare, especially by seamen, and the officer who laid these, and was looking on when the 'Cairo' went down, describes himself as feeling much as a schoolboy might whose practical joke had taken a more serious shape than he expected."

In the attack on Mobile the United States Navy had to contend against the forts protected by a line of pile obstructions between that place and Dauphin Point, backed up by a triple line of torpedoes *en échelon*. These torpedoes were of several kinds; one made of well pitched beer kegs (Fig. 62), with cones at each end, built up of pieces of wood, the exterior being carefully caulked to prevent the possibility of any moisture leaking in and so damping the powder. Five chemical fuses, as shown at F, were screwed into holes in the top. On being struck, the fuses shattered and allowed sulphuric acid to fall on chlorate of potash mixed with powdered loaf sugar, thus ensuring the explosion of the powder contained in the body of the barrel.

Another type of torpedo was constructed of tin in the form of a truncated cone (Fig. 63), the larger diameter being at the upper end. The space at this part provided the necessary buoyancy; the magazine containing gunpowder was placed in the lower portion, on top was a cast-iron cap so secured that a slight blow would cause it to fall off. The cap was made fast by a chain to a friction tube, and as it fell the weight pulled the tube, produced a flash, and exploded the charge. On looking at the diagram, an iron rod K passing through the case is shown; this fulfilled two purposes, the lower end was used for securing the mooring rope to, and the upper end for lowering the charge into position. This mine went under the name of Singer's torpedo, and was most successful during the war. Mention might be made of the safety device, which was ingenious. In the diagram a second bight of chain is shown. One link of this passed through a hole in the rod K, through which a safety-pin was passed, with a line and small float. If the weight during laying was knocked off, this safety-pin took the jar and not the friction tube. To make the mine dangerous, a small pull on the float line withdrew the safety-pin and released the second bight of chain. In 1846 as many as forty-six of the barrel mine and thirty-four of the Singer's mine were laid out in the mine-field off Mobile. These defences were

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supported by the ironclad ram "Tennessee" and a few gunboats belonging to the Confederates. In attacking the fortifications, Admiral Farragut placed his monitors first, led by the "Tecumseh" of 1034 tons, then followed the wooden ships. The leading ship had not gone very far into the danger zone when she touched a submarine mine, which violently exploded; the monitor lurched heavily, then sank bow first, taking the captain and a large number of the crew with her.

The "Brooklyn," seeing more dangers ahead, as some objects were discernible close to the surface, altered course slightly and signalled the flagship "Hartford" that there were more mines in sight. Admiral Farragut, on the signal being reported, is credited with saying, "Damn the torpedoes! Captain Drayton, go ahead! Jowett, full speed!"

Some of the ships, we read, actually felt and heard the torpedoes bump, then graze along their bottoms. Fortunately for the intrepid admiral, long immersion in salt water had caused excessive corrosion of the metal portions of the mines, which prevented the firing apparatus working effectively. In clearing this mine-field, many tugs and small steam launches were blown up causing several casualties.

Some of the torpedoes of the Confederates, when raised on conclusion of hostilities, were found to be very crudely fitted with the old gun-lock and percussion-cap, as used by Bushnell and Fulton. Generally speaking, the results obtained by submarine mines during this war considerably advanced the science of torpedo warfare, and towards the end of hostilities a very important step was made by the introduction of a mode of firing a mine at a distance by means of an electric current. This method was not largely used, but had one successful issue, that was, in blowing up the "Commodore James," a heavily armoured Federal gunboat in the Roanoke River, by a large boiler torpedo containing over 1000 lbs. of gunpowder, and supposed to be of British manufacture. Previous to this mishap the banks of the river were carefully searched for cables by the Federals, but in vain, as the operators shifted the wires in the night. This mine was fired by a galvanic battery on shore, made up of eighteen elements of a Bunsen battery, and so arranged that it could be fired from two points by a complete wire circuit to each observer. The use of electricity for firing mines has many advantages when compared with any other system, as it allows of almost perfect safety arrangements

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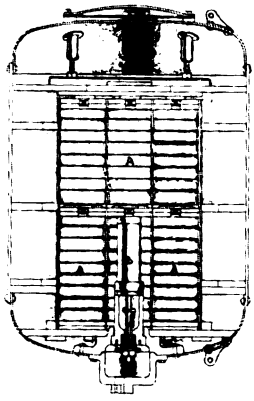

FIG. 66.—*OBSERVATION MINE.*
Containing 500 lbs. Gun-cotton (wet).
Stowed in Slabs or Copper Tins *A A A*.
B.—Primer Tin with Dry Gun-cotton.

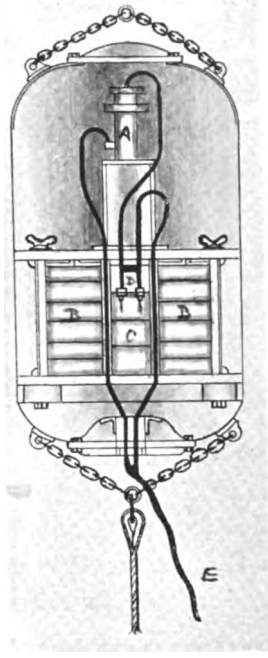

FIG 70.
76 *LB. ELECTRO-CONTACT MINE.*
A.—Circuit Closer.
B.—Gun-cotton (wet).
C.—Dry Gun-cotton Primer.
D.—Detonators.
E.—Electric Cable.

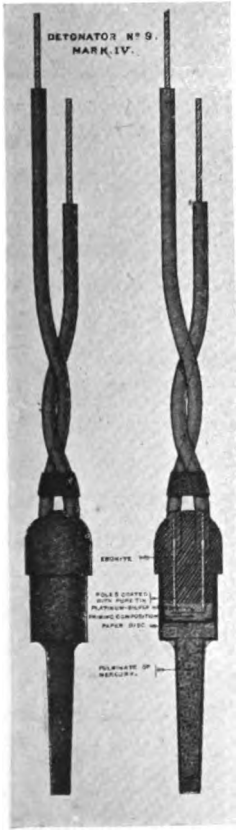

FIG. 67.—*ELECTRIC DETONATOR.*

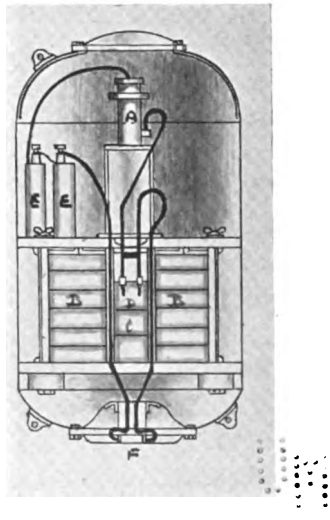

FIG. 72.
76-*LB. ELECTRO-MECHANICAL MINE.*
A.—Circuit Closer.
B.—Gun-cotton (wet).
C.—Dry Gun-cotton Primer.
D.—Detonators.
E.—Electric Cells.
F.—Circuit Breaker.

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being introduced to enable friendly ships to pass with security over the mine-fields, and moreover renders the operators, comparatively speaking, immune from danger in laying, repairing, or raising the mines.

During January 1865 the monitors kept up nightly demonstrations near the forts off the entrance to Charleston. This led to a line of sixteen torpedoes being run by the Confederates across the usual track of the monitors, with the result that the monitor "Patapsco" came into contact with one of these explosive charges, which damaged the port side under the fore-end of the ship. In fifteen seconds the vessel sank in 5 fathoms of water, drowning a large number of officers and men.

At the commencement of this war the Federals looked upon submarine mining as an underhand method of attack, but before the cessation of hostilities they pledged themselves to this mode of fighting, and even re-employed any of the Confederate mines they could raise and refit for service, thus emphasising that submarine mines were generally recognised as important weapons in coastal warfare by both belligerents.

In a former chapter we noted that the submarine boat of the "David" type, armed with the spar torpedo only, obtained some moderate success at the cost of a large number of lives. This method of taking an explosive charge against an enemy's ship had few supporters. In its place the spar torpedo was developed for use from surface boats (Plate 90). Several good attacks were made by both sides, as the Northerners retaliated by fitting up steam-pinnaces with this form of offence.

Perhaps the most dashing attack was that on the Confederate ram "Albemarle," by Lieutenant Cushing, who, in his official report, stated: "The light of a fire ashore showed me the ironclad made fast to the wharf surrounded by a pen of logs about 30 ft. from her side. We made for our enemy at full speed. In a moment we had struck the logs just abreast of the quarter-port, breasting them in some feet and our bows resting on them. The torpedo boom was then lowered, and by a vigorous pull I succeeded in diving the torpedo under the overhang and exploded it at the same time as the 'Albemarle's' gun was fired. A shot seemed to go crashing through my boat and a dense mass of water rushed in from the torpedo, filled the launch, and completely disabled her. The enemy then continued his fire at 15 ft. range, and demanded our

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surrender, which I refused, ordering the men to save themselves. The most of our party were captured, some drowned, and only one escaped beside myself, and he in a different direction."

This dashing attack called forth a letter from the Secretary of the Navy, stating that the Navy department had presented the gallant lieutenant's name to the President for a vote of thanks and promotion.

Both Federals and Confederates adapted one or more spars to their boats for attaching the torpedoes. The firing arrangements of the spar torpedoes was either a gun-lock with a percussion-cap, and fired by a line attached to a trigger, or a chemical fuse was shattered when the charge hit the ship.

The Confederate boat "Squib" was fitted up in this manner, and successfully attacked the United States frigate "Minnesota," lying at anchor in Newport News, and very seriously damaged her. I notice it related in many books on the war that the Federal ironclads ran past the forts again and again, inflicting and receiving much damage; but the forts alone could not prevent the ships from steering any course they desired. Admiral Porter, in his official despatches, wrote that "obstructions and torpedoes are a better defence than the forts of this country [United States]. No fort can keep out a fleet unless the channel is obstructed in addition."

In all, some seven monitors and eleven wooden vessels were totally destroyed when actively engaged in blockade work by submarine mines, whilst many ironclads and other vessels were temporarily disabled. In passing, it may be noted that not a single vessel was lost during this war by gun-fire, though many were structurally much damaged. When these details were promulgated to the world most maritime nations turned their attention to the development of submarine mining in all its branches.

In 1868 the Dictator of Paraguay committed a *casus belli* by capturing a Brazilian vessel in the Paraguay. This led to a disastrous war extending for a period of nearly six years. From being at first an offensive war by Paraguay, it turned into a defensive one for her, in which mining operations were used with some success by the defence. The Brazilian ironclad "Rio Janeiro" was sunk by a buoyant mine, and on one occasion the whole Brazilian fleet are supposed to have passed over a mine-field, but, through some unforeseen occurrence, no damage was done to the ships.

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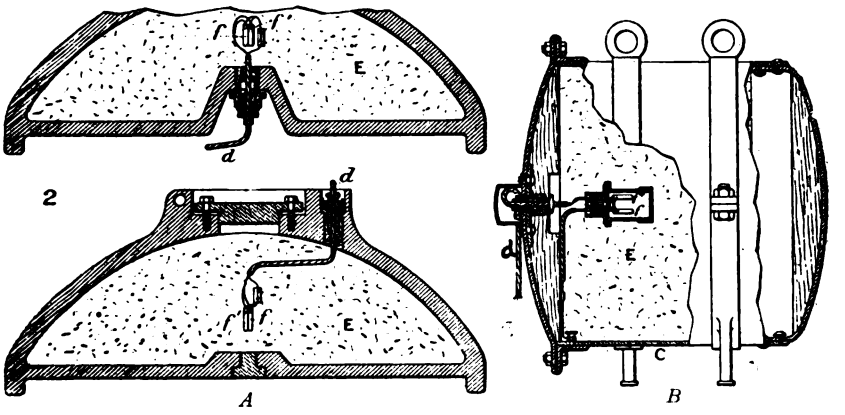

FIG. 65.—*GROUND MINE.*

A.—Old Pattern.
B.—New Pattern.
c.—Mine Case.
d.—Insulating Plug and Electric Cable.
E.—Gun Cotton.
f.—Detonators and Primer.

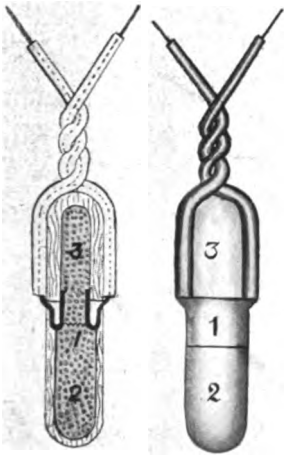

FIG. 68.—*FRENCH ELECTRIC DETONATOR.*

1.—Platinum Silver Wire Bridge.
2.—Fulminate of Mercury.
3.—Priming Composition.

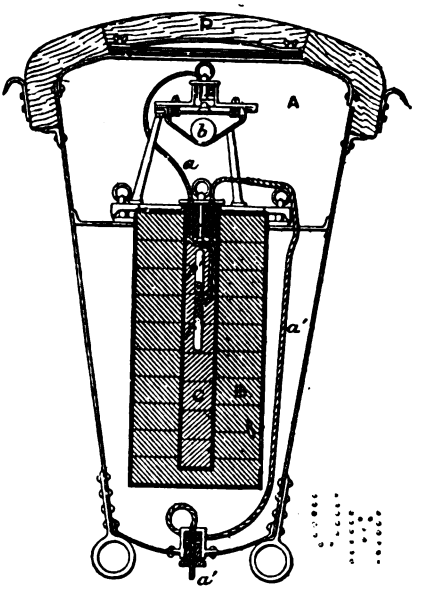

FIG. 69 —*ELECTRO-CONTACT MINE.*

A.—Buoyancy Space.
a a'.—Electric Cable.
B.—Wet Gun Cotton.
b.—Circuit Closer.
c --Dry Gun Cotton Primer.

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About the year 1870 the question of submarine mines was taken up in earnest by the authorities in this country, and a scheme of electrical mining was evolved for the protection of our principal naval and mercantile ports. This arrangement was then supposed to give the shore batteries a very powerful auxiliary system of fixed defences. Without going into any great details, it may be sufficient to know that the submarine mine protection was placed in the hands of the mining section of the corps of Royal Engineers. This defence was most efficiently elaborated at the various mining stations at home and abroad.

The navy also took a small share in the development of a rapid method of laying a mine-field—not of a permanent nature—for the protection of ships repairing or coaling at temporary bases, etc., where the resources of the submarine mining corps of Royal Engineers were not available.

The submarine mines employed in these defences are distinguishable from the locomotive torpedo, described in the next chapter, by forming a passive obstruction of a purely defensive nature. Speaking generally, since the American Civil War all maritime nations have relied upon electrically-controlled submarine mines for the protection of the waters approaching their large naval and commercial ports. These defences have formed, under certain conditions, a most essential addition to the gun armament.

The heaviest guns, as officially reported by Admiral Porter, "were not of sufficient calibre or provided in sufficient numbers to stop a ship or ships from forcing a passage unless obstacles were laid down in addition to check their advance."

These considerations resulted, during 1873–4, in a large number of explosive experiments being carried out against H.M.S. "Oberon," to actually ascertain the damage that could be done to the bottom of a ship by exploding gun-cotton charges placed in the vicinity of her hull. The "Oberon" was an old paddle-wheel steamer of 950 tons. For these experiments the double bottoms were strengthened up to represent the under-water portion of H.M.S. "Hercules," structurally the strongest ship of that day. Mines were first placed at 100 ft. from her hull, and gradually the distance was decreased until one mine was exploded so close that the ship's back was broken.

From the results of these experiments most authorities agreed that electrically-controlled defensive mines were the most suitable

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weapons for harbour protection. These were divided into two main classes:

Class I. The ground or buoyant observation mine.

Class II. The electro-contact mine.

Class I comprises all the mines that are fired from observing stations on shore. They are laid in deep water so as not to obstruct the channel for friendly ships, and can be placed singly or in lines of three, six, or more on the bottom or buoyant, and the charge varies from 500 lbs. to 1500 lbs. of gun-cotton or other high explosive. Fig. 65 shows a 1500-lb. French ground mine, (*a*) old pattern, (*b*) new pattern.* All these mines are fired by passing an electric current through a low-tension fuse or detonator. At the observation station is placed a large firing battery composed of Leclanché or dry cells; the positive pole is earthed; to the negative is attached the firing key. On the other side of the break is the main cable with an insulated core, protected by armouring leading to the line of mines; this is joined to the wires attached to the detonators in the interior of each mine and then to earth, as shown in diagram (Fig. 64). On pressing the key, an electric current—we assume for explanatory purposes—flows along the wire and brings the small, high-resistance, platinum wire bridge to a red heat; this ignites the priming composition of the fulminate of mercury detonator, which detonates the dry primer of gun-cotton, and this in turn explodes the whole charge of wet gun-cotton, picric powder, shimose, or whatever the explosive used may be.

In looking at the details of a buoyant observation mine (Fig. 66), the wet gun-cotton is built up of slabs in tiers or packed in small copper cases, the centre one is hollowed out to take the primer of dry gun-cotton, into which a pair of detonators in series are fitted; wooden platforms keep the gun-cotton in place.

The loading hole at the top of the mine and the plug at the bottom for leading the electric cable inside the case are fitted with special water-tight washers to keep all moisture from getting into the mine.

Two fulminate of mercury detonators are shown in Figs. 67 and 68; the arrangement of the conductor wires, electrodes for taking the platinum silver wire bridge, priming composition, and

* Taken from *Les Torpilles et les Mines Sous-marines*, 1905.

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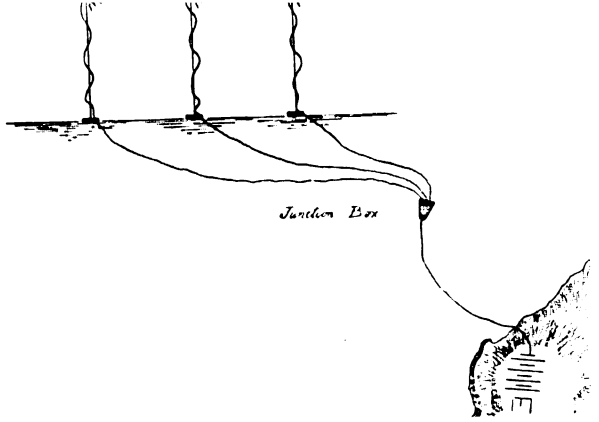

FIG. 71.—*LINE OF ELECTRO CONTACT MINES.*

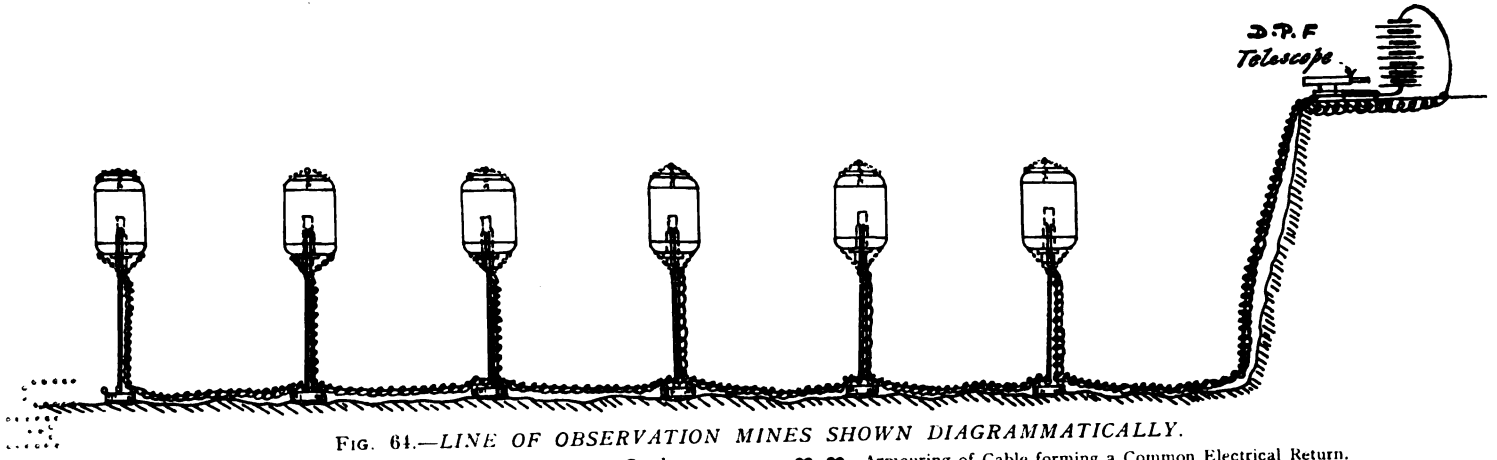

FIG. 64.—*LINE OF OBSERVATION MINES SHOWN DIAGRAMMATICALLY.*

D.P.F.—Depression Position Finder. ——— Conductor. ~~~ Armouring of Cable forming a Common Electrical Return.

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fulminate of mercury can readily be seen on examination of the drawing.

Many types of these low-tension detonators are in existence, but they are all similar in principle.

The methods in vogue for firing observation mines are:

1. A single observer, looking along pickets, fires the line of mines on pressing an electric key.

2. Intersection of sight-lines by two observers; on one operator pressing a firing key at the same instant as the other, the mines are exploded.

3. Depression position finders of various types. This instrument fires the mines when the telescope following a vessel is trained over special contact strips placed on the base plate; these are made to represent mines in rows or singly in the dangerous area; the electric current is completed for firing when a plunger on the training arm attached to the telescope touches a contact strip (Fig. 64).

In all cases the mines are under the sole control of the officer or officers of the observing stations, and can be fired when it is considered the hostile ship is over a single mine or close to a group, etc.

Plate 91 shows a British naval observation mine on the right-hand side, with a naval electro-contact mine being fitted in centre.

This brings us to a consideration of Class II.

In this system the mines, as their name implies, are fired by contact. An electric cable, as in observation mines, is joined to a battery on shore, then to mines, as shown diagrammatically (Fig. 64).

The difference in this case is that the battery is always on to the cable when the group of electro-contact mines is made active; then, on a ship striking the mine, it causes the circuit-closer in its interior to complete the electric circuit and so explode the gun-cotton. These mines are usually smaller than the observation mines and contain about 76 lbs. of wet gun-cotton.

The diagram of a British electro-contact mine shows the circuit-closer (Fig. 70) placed on a pedestal, detonators in a dry primer tin, and charge of wet gun-cotton. The loading hole and plug for taking the conductor inside the case are similar to those of the observation mine. The electro-contact mines are usually laid out in groups (Fig. 71), the branch wires being taken to a disconnector box, the function of which is to insulate the core of the branch of the first mine and prevent the bare end forming an earth, and consequently

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running the battery down, once the group is active, owing to the battery being always on to the line for the reason previously mentioned.

The advantages and disadvantages of observation and electro-contact mines (Plate 91) may be tabulated thus :—

Observation Mines.	Electro-contact Mines.
1 Can be laid in main channel.	1. Cannot be laid in main channel, as they might be struck by a friendly ship; even if the battery was off the line, the cable might foul the vessel's propellers, etc. These mines are therefore laid in by-channels.
2. Too deep to be caught by a sweep, mine-catcher, etc.	2. Can be caught by a sweep, as they are fired by contact; the distance from the surface is limited by the draught of the enemy's ships.
3. Perfectly safe with battery off.	3. Perfectly safe with battery off.
4. Cannot be seen owing to depth laid.	4. May be seen in clear water where there is a large rise and fall of tide.
5. No use in a fog.	5. Useful in a fog, except for danger referred to in No. 1.
6. An observer necessary; station liable to attack from hostile landing parties.	6. No observer necessary; the firing battery can be hidden or buried, therefore no station to attack.
7. No danger from countermining.	7. Danger from countermining in making circuit-closer signal.

The French electro-contact mine is shown in Fig. 69.* The circuit-closer consists of a ball working in a cup; on the mine being struck the ball travels to one side or the other, and completes the circuit by bridging over the upper flat plate to the

* Taken from *Les Torpilles et les Mines Sous-marines.*

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PLATE 91.—*FITTING A NAVAL ELECTRO CONTACT MINE IN H.M.S. "VERNON."*

Explosive charge 76 lbs. of Gun Cotton.

The large Mines on right of illustration are Naval Observation Mines, and contain 500 lbs. of Gun Cotton

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earthed cup, and so makes the circuit through the detonators for firing the mine.

In both observation and electro-contact mining the great disadvantage is that the area defended is so restricted, and a large quantity of cable, batteries, etc., are necessary.

Until the last few years submarine mines have been usually regarded as more in the nature of fixed defences than for offensive purposes. But now offensive mines have come to be recognised as of the greatest importance. These are subdivided into: Class I, the mechanical mine; Class II, the electro-mechanical mine. We have previously described how very effective the barrel and Singer's mines were in the American Civil War. Yet another type is the old British shot mechanical mine, designed on the same principle as the Singer's; a hostile vessel, on hitting the mine, was supposed to knock the shot off, this, on falling, pulled the friction tube lanyard and exploded the mine.

The Russian mechanical mine, as used in the Crimea, has been also referred to; from this type was evolved their present electro-mechanical mine (page 281).

In Class II we have the electro-mechanical offensive mine. These contain their own means of ignition. A circuit-closer is placed inside the mine, as in electro-contact mining, but instead of a long length of cable supplying a current of electricity from a battery on shore, a few Leclanché or dry cells are placed in the interior of the mine (Fig. 72).

To allow of safety in laying, a circuit-breaker provides additional security; this is merely a contrivance by which two contacts are kept apart by an insulator of solidified sugar, or some such soluble substance. After immersion for half an hour or so, the sugar melts and one contact is forced against the other by a powerful spring; this only leaves the break at the circuit-closer. On the mine being struck when in such a condition, the circuit-closer completes the electric circuit, fires the detonators, and explodes the mine.

During the Franco-German war of 1870–1, the moral effect of the submarine mine was amply demonstrated. The Germans defended their principal harbours and estuaries in the Baltic and North Sea with mechanical and electro-mechanical mines; the former contained 80 to 100 lbs. of gunpowder and the latter 200 lbs. of dualine.

The port of Kiel was defended beyond Friedrichsort by mechanical

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mines on the sides of the main channel, with observation mines in the middle, capable of being fired in groups by an observer on one of the forts.

In addition to the mine defences, chain cables, timber rafts, etc., formed additional obstructions, the whole being under the protection of the local batteries. No opportunities occurred during the war of testing the efficiency of these precautions, as the mere fact of the mines having been laid prevented the French fleet from undertaking naval operations on any scale. On raising their mine-field the Germans are reported to have lost a large number of lives.

At the commencement of hostilities between Russia and Turkey in 1877, the Turkish fleet in southern waters was distinctly superior to the Russian naval forces. We find both sides made use of submarine mines for defensive purposes; the results were disappointing, as only one Turkish gunboat was sunk by a mine; this occurred at Soulina in October 1877. The admiral in command of the Soulina squadron knew perfectly well the Russians had mined the river, nevertheless he gave orders for the "Kartel," a paddle-wheel tug, and the gunboat "Suna" to examine the river. Shortly after leaving the anchorage the "Suna" struck a mine under her port bow. The effect of the explosion damaged the whole forward end, causing her to sink head foremost, and in a few minutes the masts alone remained above water.*

Several torpedo-boat attacks were made during this war with towing and spar torpedoes.

In the first attack at Batoum a Russian torpedo depôt ship, the "Grand Duke Constantine," carried four second-class torpedo-boats and dropped them within a few miles of the Turkish fleet, with orders to attempt to destroy some of the ships by means of towing torpedoes.† The result of this attack was a failure. Though one torpedo actually struck a Turkish transport under the quarter, it failed to explode.

The captain of the torpedo depôt ship was Lieutenant Makaroff, the same gallant officer who lost his life on board the "Petropavlovsk" ‡ when in command of the Russian squadron during a sortie off Port Arthur.

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* *Torpedo Warfare*, Sleeman.

† These were of the Harvey pattern, Chapter XXII.

‡ See page 283.

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PLATE 92.—*FIRING A LINE OF COUNTERMINES OFF MALTA*, 1904.

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A few days later the Turkish monitor "Duke Saife" was attacked by four Russian torpedo-boats armed with spar torpedoes. One was exploded under the port quarter, but did not sink her; therefore another boat attacked, and after the second explosion the monitor sank in a very few minutes, drowning most of the crew. In the Russian boats the loss of life was insignificant.

Countermining.

A submarine explosion produces two effects:

1. The direct effect formed by the gases displacing the water; this forms a water projectile.

2. The indirect effect which is felt outside the disturbed area for a considerable distance. This is a wave of compression radiating outwards with considerable velocity.

The direct blow of the water projectile is the one we depend upon to penetrate the bottom of a ship.

The indirect effect is used in the system of countermining. This is simply to run a line of mines over an enemy's mine-field and explode them (Plate 92), so that the wave of compression extends over a large area and causes mine cases to bulge in and leak, thereby sinking the mine, or the circuit-closer of the electro-contact mines may be made to signal and so explode the mine. The channel is then cleared by dragging a bight of cable or wire hawser over it, as a further precaution, before allowing ships to pass (Fig. 77a).

In a letter dated June 1898, from Admiral Sampson to General Shafter, in reference to forcing an entrance to Santiago, the following passage occurs:—

"Our trouble from the first has been that the channel to the harbour is well strewn with observation mines, which would certainly result in the sinking of one or more ships if we attempted to enter the harbour; and by the sinking of a ship the object of the attempt to enter the harbour would be defeated by the preventing of further progress on our part. It was my hope that an attack on your part of these shore batteries would leave us at liberty to drag the channel for torpedoes. If it is your earnest desire to force an entrance I will at once prepare to undertake it. I think, however, that our position and yours would be made more difficult if, as is possible, we fail in our attempt. We have in our outfit at Guantanamo forty counter-

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mining mines which I will bring here with as little delay as possible, and if we can succeed in freeing the entrance of mines by their use I will enter the harbour. This work, which is unfamiliar to us, will require considerable time. It is not so much the loss of the men as it is the loss of ships which has until now deterred me from making a direct attack upon the ships within the port."

The army had lost some 500 men, and the General thought the navy should have a turn, and in previous correspondence pressed the admiral to force an entrance. However, before any torpedo operations could be undertaken the Spanish fleet came out of harbour on July 3rd, and was brought to action with most disastrous consequences. On reviewing this war from a torpedoist's point of view, it seems scarcely credible that the Americans could have neglected to practise countermining as a method of forcing mine-fields.

The Italian Navy, in some skilful manœuvres that took place a few years ago, practically demonstrated how submarine mines could be used as offensive weapons. Hitherto they were regarded as fixed defences of seaports, or were used as blockade mines for sealing a hostile fleet in port. This latter function of the mine would seldom be necessary, as, generally speaking, the blockading squadron is the superior belligerent in that locality; therefore the admiral would, no doubt, prefer to draw his opponent out rather than prevent egress. To hamper the ships returning, or reinforcements from entering a port, the offensive mine is especially adaptable.

The Italians showed how fleets could be forced over mined areas. This lesson Japan appears to have learnt well. Of recent years improved safety arrangements have been devised for use with the offensive mine, and also all nations have developed a depth-taking apparatus to enable mines to be dropped at great depths, and by means of automatic devices the distance the mine is placed under the surface is gauged very accurately. This system was first invented by Lieutenant Ottley * in the well-known mining apparatus named after him.

In Austria, Lieutenant Pieuteuski developed the Ottley gear. In Japan, Commander Oda has invented a very efficient automatic depth attachment on the Ottley principle.

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* Now Captain Ottley, R.N., Director of Naval Intelligence.

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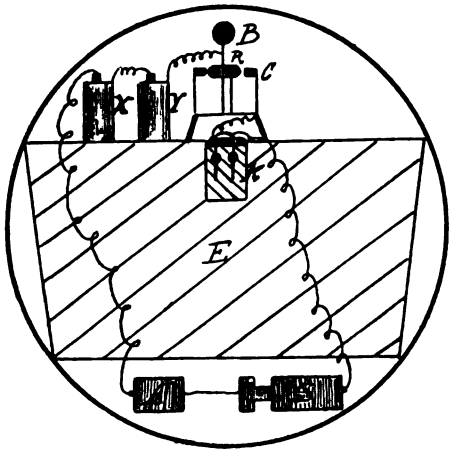

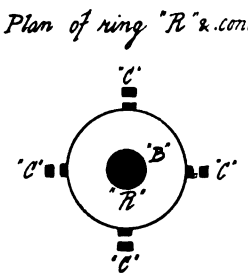

FIG. 73.—*CIRCUIT OF JAPANESE OFFENSIVE MINE, CYLINDRICAL TYPE.*

A.—Mechanical Circuit Breaker made active on letting go.
S.—Soluble Circuit Breaker, dissolves and makes contact in half an hour.
X & Y.—Dry Cells.
K.—Detonators.
R.—Contact Ring.
C.—Contacts.
E.—Explosive (Shimose).
B —Pendulum knob. On MINE being struck, knob vibrates and ring "*R*" makes contact with contacts "*C*," and so completes the Electric circuit.

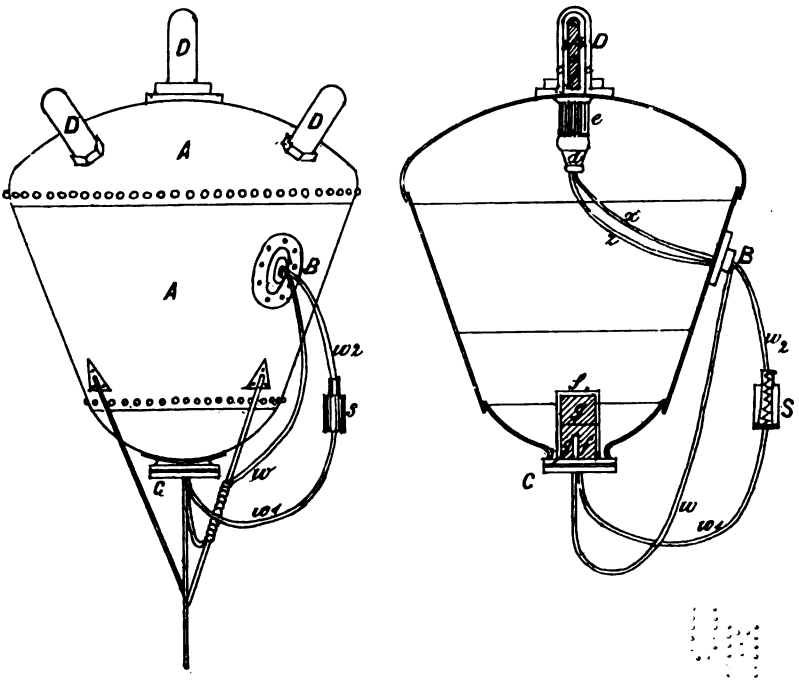

FIG. 74.—*RUSSIAN ELECTRO-MECHANICAL MINE.*

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The mechanical or electro-mechanical offensive mine, as we have seen, is quite self-contained: that is, they are in no way controlled from the shore. Once laid, they are dangerous to any friendly, neutral, or hostile ship that may come in contact with them, either when moored or drifting. Considerable care is required in handling mines of this nature, and none but competent trained men should ever be allowed to touch them. During the recent war the Japanese had one accident from improper handling of these weapons. This occurred in the mine-laying ship "Taikoku Maru," a merchant vessel fitted up for mining work.

Whilst a party of men were employed in fitting mines one accidentally exploded, killing an officer and nearly twenty men. The ship sustained little damage from the explosion.

The Japanese offensive mines have been built cylindrical, truncated, or spherical. The charge consisted of shimose powder, which was fired by electricity.

The circuit went from the negative pole of two dry cells to the heavy pendulum knob shown in diagram (Fig. 73); this was insulated. The positive pole was connected to a clock device used as a mechanical circuit-breaker, then to a soluble circuit-breaker up to the detonators, which were connected to the contact-studs. After the mine was laid the clockwork device revolved for half an hour or so, and towards the end of its run an electro-contact was completed; the soluble circuit-breaker likewise made contact when the sugar melted in the salt water, consequently only one break was left at the circuit-closer. On the mine being struck, the heavy pendulum vibrated and hit one of the contacts, completed the electric circuit, and so fired the mine.*

Although the electro-mechanical mine used by Russia has been invented for a large number of years, it is none the less effective, and is the same type as was employed in the Turko-Russian war, the shape now being usually spherical or conical (Plate 95).

In the diagram (Fig. 74), A is the conical-shaped case, B the loading hole, C the base plug; DD, etc., are five horns screwed into the head of the case A; these are composed of a glass tube *a*, containing a chlorate of potash mixture, enclosed in a lead tube *b*, over which is screwed a brass safety cylinder C; when ready for action

* From details furnished by Commander O., I.J.N.

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this latter tube *c* is removed; directly beneath each of the horns D, on the inside of the case, as at *e*, is a thin brass cylinder, closed at one end by a piece of wood *d*, and containing several pieces of zinc and carbon, arranged in the form of a battery, the zinc and carbon wires, *z* and *x*, being led through the piece of wood *d*; *f* is a copper cylinder containing the priming charge of gun-cotton *g*, and detonating fuse *f*; the terminals of the fuse are connected to two insulated wires, *w* and w_1, the former of which is led direct to the loading hole B, and attached on the inside to the five zinc connecting wires *z*, etc.; the latter is attached to one end of a safety arrangement S, the other end of which is connected to the wire w_2, which is attached on the inside to the carbon wires *x*, etc.; the safety arrangement S consists of an ebonite cylinder, containing a brass spiral spring fixed to one end of it, and pressing against a brass plate at the other, thus preserving a metallic connection between the wires w_1 and w_2; the mine is rendered inactive by pressing the spring down, and inserting a piece of ebonite between it and the plate.*

According to the torpedo lieutenant of the "Bayan," when writing to the *Rousskii Invalid*, the Russian mine contained 250 kilogrammes of high explosive, usually gun-cotton.

After the successful attack made by the Japanese torpedo-boats on the night of February 7–8, 1904, the Russians realised the tremendous blow that had been struck at their naval supremacy in the East. The authorities were thus face to face with a very grave state of affairs, and at once commenced to lay mines across the entrance of Talienwan Bay to protect Dalny from any attack; all these belonged to the electro-mechanical type, and were laid by the armed mine-layer "Yenisei" of 2500 tons. Whilst laying the three hundred and first mine, one previously dropped came to the surface, and in clearing it the mine-layer fouled the last laid with her bows; a severe explosion occurred, and the "Yenisei" sank rapidly, taking with her most of the crew. Only a few survivors were picked up. The Russians, in addition to these electro-mechanical mines, laid three lines of observation mines in the outer anchorage of Port Arthur, 3 to 4 kilometres from the entrance, the interval between the lines being 150 to 200 metres. No record can be found of any of the Japanese ships passing over these mines.

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* Taken from Lieutenant Sleeman's *Torpedo Warfare*.

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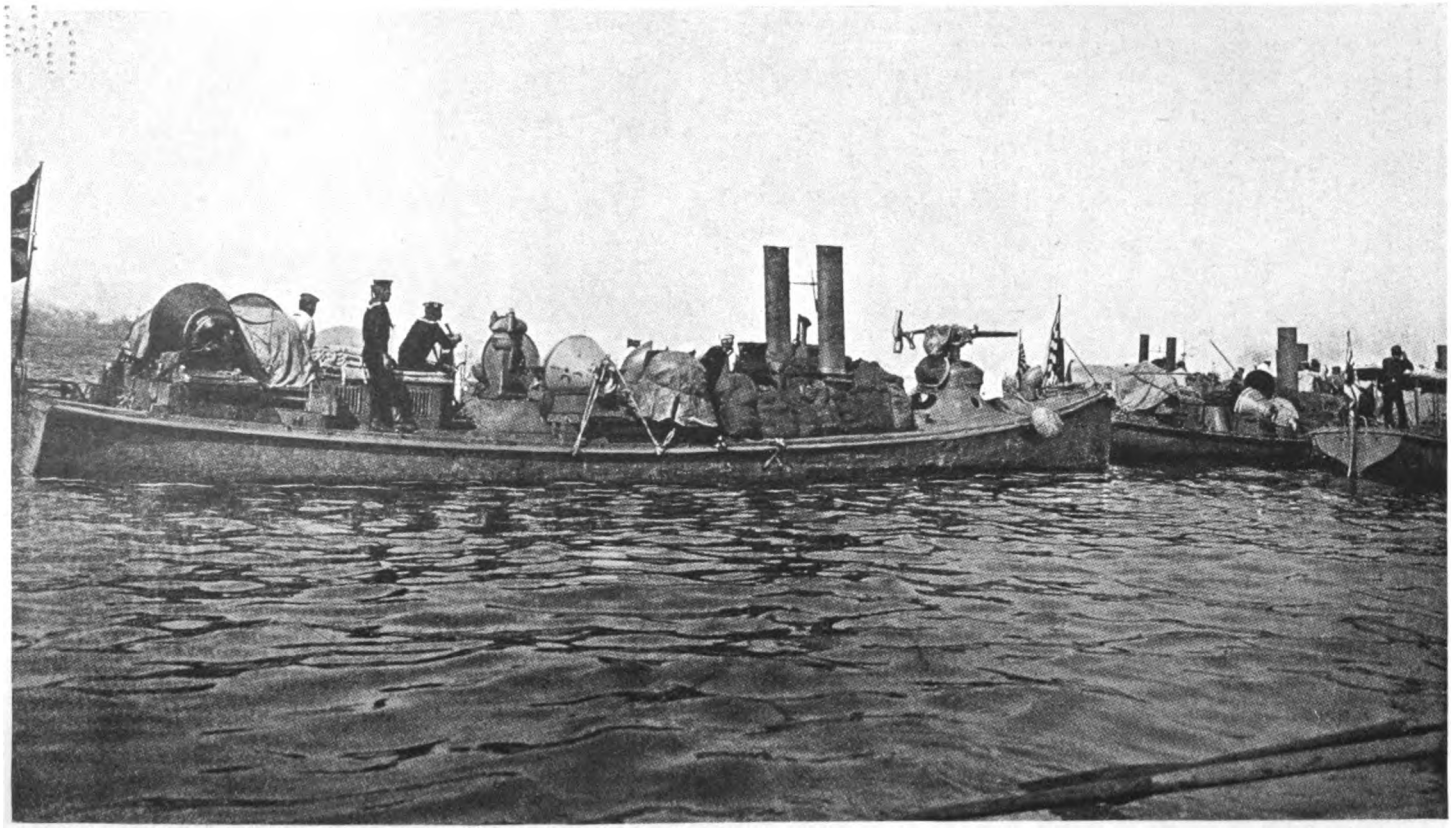

PLATE 93.—*JAPANESE PICQUET BOATS RIGGED FOR DROPPING OFFENSIVE MINES OFF PORT ARTHUR*, 1904.

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On the night of April 12–13, 1904, the Japanese sent a mining expedition of destroyers, torpedo-boats, picquet boats, and mine-layers to operate off Port Arthur; a pretended torpedo attack was made to screen the mine-layers, and during this feint mines were dropped from the destroyers and the mining vessels right across the channel usually used by the Russians (Plate 93).

The next day a weak decoy squadron was sent by Admiral Togo to draw the Russian fleet out of Port Arthur, the main Japanese fleet being kept out of sight, but in wireless telegraphy touch with the detached ships. During the morning the Russian squadron proceeded out of harbour, consisting of—

Battleships:	"Petropavlovsk" (flagship of Adm. Makaroff),	"Pobieda," "Poltava."
Cruisers:	"Novik," "Diana,"	"Askold," "Bayan,"

and gave chase to the decoy squadron, which then made off, but kept in wireless telegraphy touch with the main squadron below the horizon. After some time the latter appeared in sight. The Russians were not apparently ready to try conclusions with their enemy, and therefore the admiral signalled to his fleet to return to Port Arthur. Suddenly, under the starboard side of the flagship, a column of water was thrown up, followed by several dull reports—it is believed the Japanese mines were coupled together—and when the bow of the "Petropavlovsk" (11,000 tons) touched the connecting cable she carried it with her and swung the two mines with considerable force against her side, probably one to port and one to starboard.

The terrific shock may also have detonated the explosives in one of her magazines, for the ship disappeared bow first, with a heavy list to starboard, within two minutes of the explosions; only some forty men out of a crew of seven hundred were saved (Fig. 75).

This was a severe loss to the Russians, as Admiral Makaroff was the most brilliant scientist in their navy. He may be remembered by many in this country as the designer of the ice-breaker "Ermack," built on the Tyne at Elswick. As the other ships were making their way back to Port Arthur after the loss of the flagship, the battleship "Pobieda" (12,670 tons) struck a mine under her bows and was severely damaged, the water flooding aft as far as the capstan engine compartment. This did not prevent the harbour being reached, in

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which repairs were made by means of a cofferdam; these were executed in sufficient time to allow her to take part in the sortie of August 10, 1904.

The Japanese fleet was destined, before the end of the following month, to be paid out in their own coin, and their navy to receive the severest blow of the whole war. When cruising with the fleet to the S.E. of Port Arthur, some 10 miles from the shore, on May 15, 1904, the Japanese battleship "Hatsuse" (15,000 tons) struck two mines, which detonated one of her magazines and caused her to sink in deep water, with most of the crew. This mine-field was skilfully laid by the Russian transport "Amur," the mines being placed 100 ft. apart for a distance of 1 mile. On the same day the Japanese battleship "Yashima" (12,500 tons) struck a mine off Dalny, and had eventually to be beached in shallow water on her way home to Japan for docking. The loss of these two ships was a crushing misfortune to Japan, and meant the loss of one-third of her battleship squadron in a single day. The loss of the "Hatsuse" was admitted at the time, but that of the "Yashima" was kept a secret until the conclusion of hostilities, and then generally made known.

The "Hatsuse" incident has led to much discussion in the press on the right of belligerents to lay mines in the high seas. If they are laid within territorial waters of either Power no objection can possibly be made by neutrals. The territorial limit of 3 miles, sometimes spoken of as the marine league, was laid down as the limit of range of artillery of the early days. Now that the range of modern guns has been increased to 10 or 12 miles, it seems absurd to have a 3-mile limit. Some authorities say it is inadmissible to extend the marine league, because as now fixed it prevents dominion over large areas of water.

The old Roman law laid down that territorial waters extended up to the middle line. With the increased range of modern guns it is futile to argue that if a ship can shell you at such an extended range you should not be able to retaliate by laying a drifting or fixed mine-field in an attempt to inflict as much damage to her as possible.

Under modern conditions the territorial limit might with advantage be extended. The argument against any increase, by some authorities in this country, is usually summed up thus. Supposing France and England were at war, then the whole Channel would be mined. This either belligerent would most assuredly make a strenuous

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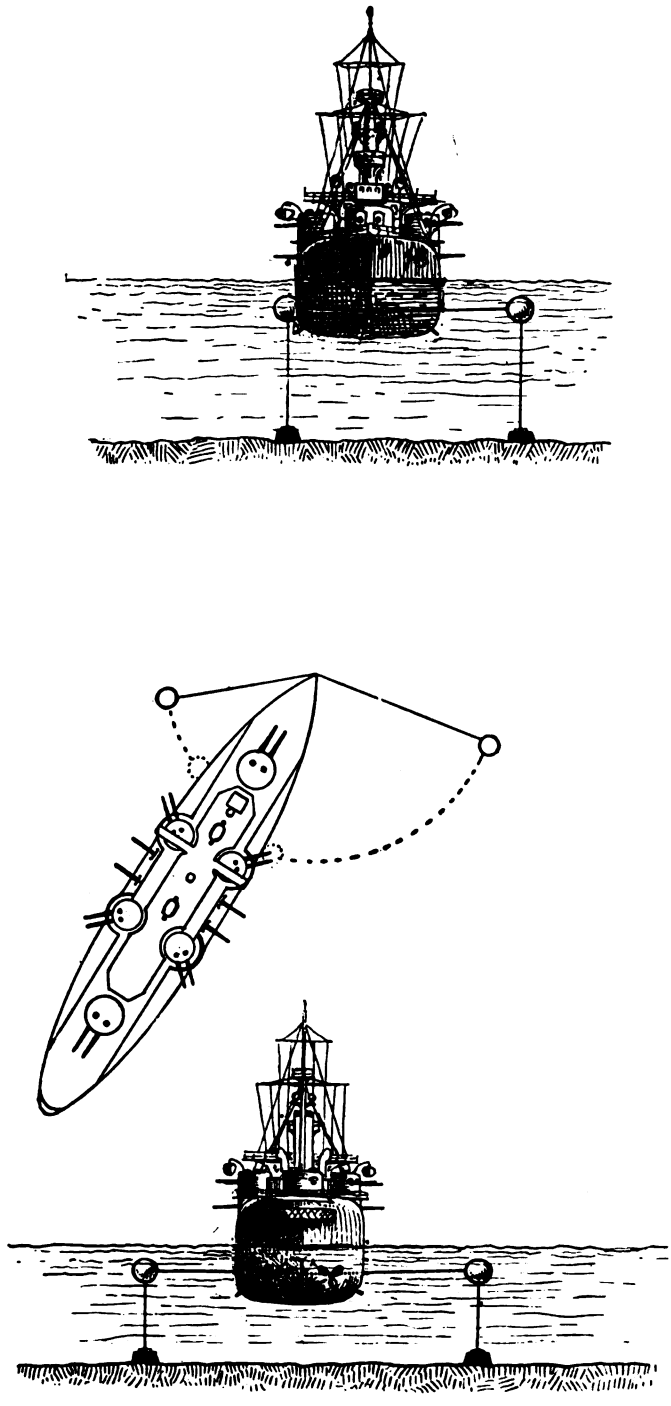

FIG. 75.—*DIAGRAMS SHOWING HOW ADMIRAL MARAKOFF'S FLAGSHIP "PETROPAVLOVSK" WAS SUNK BY THE EXPLOSION OF TWO JAPANESE OFFENSIVE MINES, CONNECTED TOGETHER BY A WIRE HAWSER, OFF PORT ARTHUR, 13th APRIL, 1904.*

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attempt to do. Neutrals would be warned of the dangers, and need not use the Channel unless they care to take the risk, and our own merchant ships would be similarly cautioned. It must be emphasised that commercial interests will at times have to be sacrificed should national needs demand it.

On June 23rd, Captain von Essen's ship, the "Sevastopol" (11,000 tons), was sent outside the harbour to drive off several Japanese cruisers that were shelling the line of fortifications to the east of Port Arthur. This was accomplished; but in returning she struck a Japanese mine, which blew in many square feet on the starboard side, abaft the foremast, at a depth of about 7 ft. below the water-line. The rent was from 7 to 10 ft. in depth, and 35 ft. to 40 ft. in length. The frames, ten in all, were bent inward or torn entirely apart, and the plating blown bodily into the ship. She was taken into the inner harbour, and a repair caisson was used to enclose the injured portion of the hull, in the manner shown in the diagram (Fig. 77). The caisson was built of 9 in. by 9 in. timbers, tongued and grooved and dovetailed. The floor, which was from 17 to 22 ft. in width, rested against the bilge keel, and the outer wall, which was at a distance of about 10 ft. from the hull, had a total depth of from 32 to 35 ft., the length of the caisson being about 75 ft. Knee-bracing of heavy timbers was worked in between the floor and the wall, and the construction was further stiffened by heavy diagonal bolts, which passed through from floor to outside wall, as shown in sketch. The joint where the edge of the caisson abutted on the hull of the ship was formed of hemp packing covered with canvas; the whole of the outside of the caisson was covered with canvas, and outside of this a heavy coating of hot tar was laid on. The caisson was then floated into position, and drawn up snugly against the side of the ship by means of cables, some of which passed entirely underneath the ship and were drawn tight on the port side, while others were attached to the top edge of the caisson and were led across to the steam winches on deck. After the caisson had been drawn to a snug fit the water was pumped out, and the hydraulic pressure served to hold the caisson tightly against the hull. The damaged plating was then removed by cutting off the rivet heads, and the broken portions of the framing were cut away. While this work was proceeding, new frames and plates were being prepared in the dockyard shops. The frames were built into the ship, the plating riveted on, and the

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vessel finally restored to first-class condition. The whole of the work was accomplished in six weeks' time, which, considering that the shops in which the new framing was prepared, and the ship herself, were under fire, must be regarded as a most remarkable and highly creditable performance * (Figs. 76 and 77).

Again, on September 20th, the "Sevastopol," whilst operating outside the harbour, was once more struck by a mine on the starboard side. This time the charge was a heavy one and did much damage. A cofferdam, as before, was built over the injured part and the work of repair successfully accomplished in the space of two months or so. It is noticeable that the "Sevastopol" was kept on an even level by flooding wing compartments on the opposite side to counteract the inflow of water. This method of compensating for injuries below the water-line is fully dealt with in Chapter XXIII. Towards the end of November 1904 the old Japanese cruiser "Sai Yen," formerly the Chinese "Tsi Yuen," struck a mine off Port Arthur and was sunk, the captain and many of the crew being drowned; the cruiser "Takasago" ran on a mine off Port Arthur on the following December 14th; also the "Miyako" was blown up in a similar manner in Talienwan Bay. Several gunboats, as the "Hei Yen," "Kaimon," and many destroyers on both sides, were put out of action or completely destroyed during the war. A large number of offensive mines were laid off Vladivostock before the Japanese squadrons moved south to meet the Baltic squadron, but from all accounts the Russian cruiser "Gromoboi" was the only warship to suffer any damage, and this occurred when she left Vladivostock to meet Admiral Rozhdestvensky's squadron; a mine struck on the side of a coal bunker opening into the stokehold and made a hole about 40 ft. long by 16 ft. in depth. Fortunately the wood-sheathing of the ship jammed the hole up to such an extent that the pumps could keep the water under. In the great battle of the Sea of Japan, mines were not used, as was done in the August 10th fight off Port Arthur, when torpedo-boats laid mines across the bows of the Russian fleet and compelled them to alter their course frequently, a delay which allowed the main body of the Japanese fleet to come up.

During the long siege of Port Arthur the following repairs were successfully carried out:—

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* *Scientific American.*

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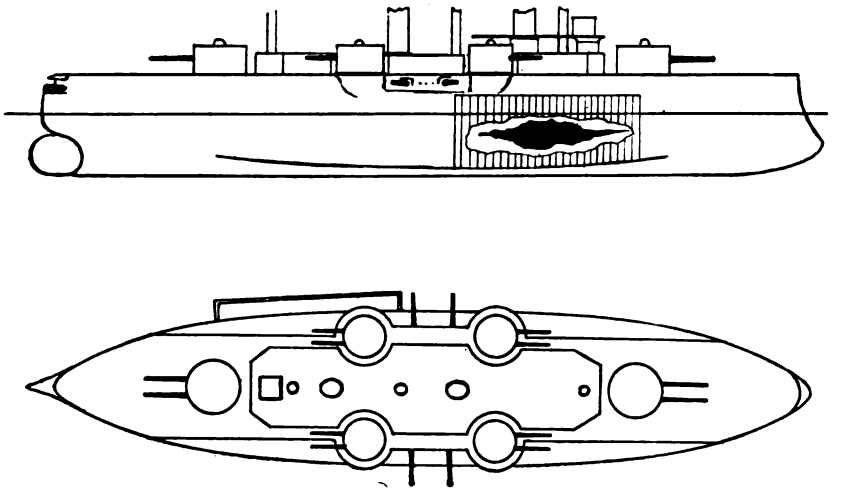

FIG. 76.—*OUTBOARD PROFILE AND DECK-PLAN OF THE "SEVASTOPOL," SHOWING THE COFFERDAM, AND (IN BLACK) THE AREA OF HULL AFFECTED BY THE MINE EXPLOSION.*

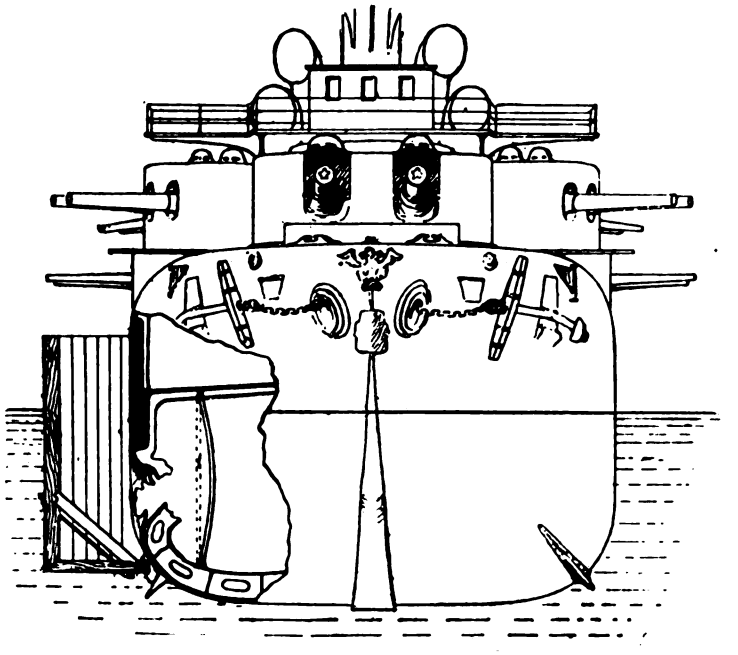

FIG. 77.—*SECTIONAL VIEW SHOWING THE WATER-TIGHT CAISSON 10 FEET WIDE, 35 FEET DEEP, 75 FEET LONG, BY WHICH THE INJURED SIDE OF THE "SEVASTOPOL" AND OTHER BATTLESHIPS WAS LAID CLEAR OF WATER WHILE THE WRECKED STRUCTURE WAS REMOVED, AND NEW FRAMES AND PLATING WERE BUILT IN PLACE.*

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Battleships.—"Sevastopol," twice injured by mines and repaired by means of a cofferdam.

"Cesarevitch," injured by a torpedo in the first attack and repaired by means of a cofferdam.

"Retvizan," injured by a torpedo in the first attack and repaired by means of a cofferdam.

"Pobieda," struck a mine and repaired by means of a cofferdam.

Cruisers.—"Pallada," injured by a torpedo in the first attack and repaired by means of a cofferdam.

"Boyarin," injured by a torpedo, Feb. 14, 1904.

In addition to these injuries much structural damage was done by shell-fire. It would be interesting to know who the great leader was in this heroic effort to make the ships efficient, in spite of the repairs being undertaken more or less under gun-fire. It is generally believed that the railway engineers played a large part in so skilfully repairing the damaged warships. The few incidents just recorded show what an important part offensive mining played in the late war.*

Turning to questions on mining operations in connection with the coast defences of this country, we find that the elaborate and costly † system of fixed mine-fields, perfected by the submarine mining corps of Royal Engineers, has recently been subjected to much criticism.

Two important points appear to the writer to have been overlooked by the critics. The first, which may not be generally known, is this. In choosing the position of the mine-fields, the Admiralty were always consulted by the War Office on the area to be defended. As can be imagined, a dual responsibility over a system of defence which involved questions of a controversial nature was never really satisfactory, and it had long been felt by many naval and military officers that in open channels, with deep water and strong tides, etc., the employment of fixed mines was very difficult and at times might be quite ineffective; also to sink a hostile ship right in the fairway of an approach to an important naval port was not a satisfactory solution

* Russo-Japanese war, 1904–5.

† One authority states that the outlay on Royal Engineers mining defences was some £1,500,000, and necessitated for upkeep an annual expenditure of £250,000.

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of port defence, and might have consequences the reverse of what was intended.

The second point is that all the apparatus in use was designed most carefully for being kept under water for lengthy periods, and was also required to last a great number of years. Consequently the high cost of manufacture was repaid to a certain extent by the duration of the material.

During the whole time the Royal Engineers worked at their mine defences, I am given to understand, on the highest authority, that they had no accidents at home and only one slight mishap abroad. This alone speaks volumes for the systematic training given to officers and men in the handling of explosives.

The Esher Committee were of opinion that mining work could be better performed by the navy, and subsequently the naval and military authorities, aided by the Committee of Defence, decided that the policy of a stationary mine defence was the wrong one for this country.

No reflection of any description was cast on the Royal Engineers. This change in coast defence, the Army Council state, was due to the requirements of Imperial defence; and they placed on record, in high terms, the satisfactory and efficient manner in which the mining duties were carried out by the Royal Engineers. Approval was ultimately given for the abolition of fixed mining defences in all naval and commercial ports of the Empire.

The remedy for the limitations of the passive mine-field for defensive purposes is now being sought in the utilisation of the submarine boat, which can be looked upon as an outlying torpedo station. That is, the whole system of a purely defensive controlled mine-field has been abolished in favour of the more mobile defence of submarine boats.

The reader must not be confused in this decision, and consider that mining as a whole has been abolished. Only one branch of it will disappear, that is, the defensive controlled mine-field, leaving offensive mining—a system which, no doubt, most nations will devote some considerable attention to in its further development, and add mine-layers, like H.M.S. "Iphigenia" (Plate 94), to their sea-going fleets.

The United States authorities have considered the question of building submarines capable of running a line of mines; the use of these craft for this purpose is quite practicable and could be developed.

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PLATE 94.—*H.M.S. "IPHIGENIA" FITTED AS A MINE LAYER, WITH STERN CUT AWAY TO FACILITATE DROPPING THE MINES.*

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The locomotive torpedoes carried might be reduced in number, and if the superstructure was recessed so that mines could fit in snugly, by arranging pneumatic releasing gear on the Drzewiecki* system of firing torpedoes, no insurmountable difficulty need be experienced in fitting submariñes for this service, should it appear desirable to do so. On the mines being dropped, water ballast could be taken into special tanks for compensating purposes, as is now done in the Holland boat when discharging torpedoes.

Submarine boats lend themselves to towing operations, and could be easily dropped off an enemy's port by any fast vessel during the night. On daylight breaking, the boat could get as close as possible off the entrance and run a line of six special mines across the main channel. Having fulfilled her mission, the submarine would then make the best of her way out of it. There can be little doubt sub-surface mine-layers will be developed in the future for hampering the entrances to fortified harbours.

Sweeping for mines with submarines has been suggested. In this case two boats could trail a bight of a wire hawser over the area ordered to be cleared, and, being under fire, would only show their periscopes. A detached portion of the fleet, provided hostile submarines did not exist, or had been accounted for, could keep watch and prevent destroyers, etc., from interfering with the sweeping operations. This would be a hazardous undertaking; but, by the example the Japanese have set us in facing dangers for their country, I fancy volunteers for this service would not be lacking in most European navies. For purely defensive work the submarine boat may be of the greatest value when placed in look-out positions at the end of a cable and trimmed ready for diving or anchored submerged, all the time being in telegraphic, telephonic, or wireless communication with a look-out controlling station on shore. Any boat efficiently operated in this manner would certainly be a most formidable mode of defence. Two or three boats off a port may be looked upon as the natural development of the passive mining system into a mobile defence. The rapid advance of modern science has made this quite practicable, and it is in this direction that the defence of our coasts must be developed. Submarines on their patrol grounds must be prepared for instant attack in any direction. Rapid methods of running a telegraph cable to a valuable

* See Chapter XXII.

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point d'appui and placing a submarine there should receive some attention.

Also, with water as a medium, submarine signals can be transmitted at about 4700 ft. per sec. Experiments in this direction have been held in Narragansett Bay, U.S.A., embodying a system of communication under water between submarine boats, or between a submarine boat and the shore, or between a submarine boat and a warship. The submarine torpedo boat "Shark" has been equipped with an apparatus for receiving sounds, and on September 8, 1904, it is reported, messages were sent from her by pounding on the inner walls of her hull, but merely as an experiment, and not as a method. Newport advices stated that it was shown that even sounds not musical were easily detected at a great distance. The position and the sailing direction of the torpedo-boat "Stiletto" was determined on board the submerged "Shark" by use of the apparatus, the "Stiletto" being more than a mile away. It was the rapid beat of her screw that gave the signal and aided in the finding. It was found that neither depth nor pressure was a disadvantage in the matter of using the signal. The gunboat "Peoria" has been equipped with the apparatus, and the development of a system of communication for use in the U.S. Navy begun in earnest. The signalling is communicated through the water by sound waves, which set up vibrations in the receiving apparatus placed in the outer skin plating of the hull, and are heard in suitable telephones. So delicate is the transmission that, by varying the tone or the quality of the sound, a very satisfactory scheme of conversation can be arranged.*

Most maritime nations have been trying this system for communication between ships of the mercantile marine and light-vessels. The results have been very successful, and no doubt improvements will be made to intensify the vibrations and enable accurate reception to be obtained.

Some sound-signal experiments† have been undertaken in our submarines, in connection with which we unfortunately have to chronicle a mishap to "A 4." On carefully scrutinising the evidence given before a court-martial, we find that the boat was being

* Extract from an American Report.

† A system of submarine sound-signalling has recently (1907) been tried between H.M. ships "Antrim" and "Spanker," with, it is believed, very satisfactory results.

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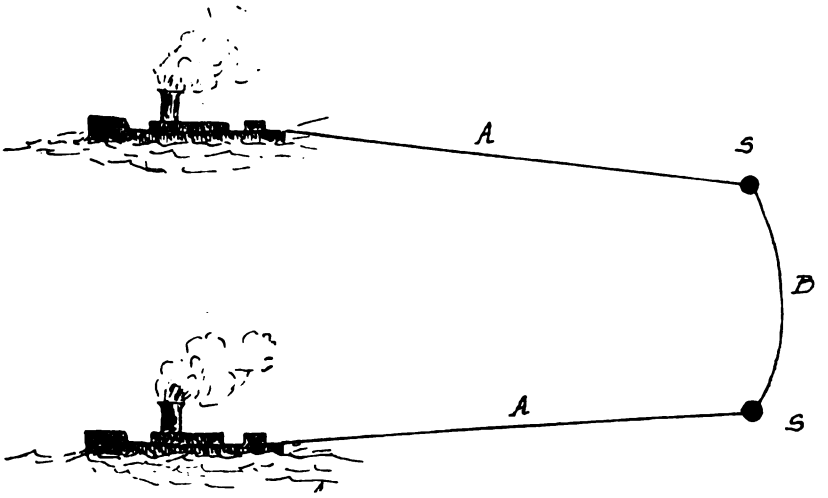

FIG. 77A.—*SWEEP USED BY THE RUSSIANS TO CLEAR THE CHANNELS OFF PORT ARTHUR FROM JAPANESE OFFENSIVE MINES.*

A.—Tails of Sweep 2-in. Wire.
B.—The Sweep 2-in. Wire.
S.—1¾ cwt. Sinkers.

PLATE 95.—*A RUSSIAN ELECTRO MECHANICAL MINE BEING UNFITTED BY THE JAPANESE*, 1905.

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trimmed to an awash condition, not for the intention of diving, but so as to submerge the hull for the purpose of receiving the sound vibrations. The kingstons were opened, and water ballast was taken into the boat. As has already been pointed out in the case of the French boat "Farfadet," if this water ballast is taken in too quickly towards the end, downward momentum is easily obtained, though with some considerable amount of buoyancy. In this case the downward momentum caused the boat to dip her ventilators under, one of which had been left open for visual signalling to the ship carrying out the sound experiments. A considerable amount of water came in through the ventilator, all buoyancy was destroyed, and the boat reached upwards of 90 ft. before her downward momentum could be checked. The water flooded the electric accumulators and short-circuited the internal lighting circuits; this put the boat in perfect darkness; also the swishing about of the salt water caused many sparks, as short circuits occurred, added to which the metal fittings became electrified by the exciting liquid—salt water running all over the top of the battery. The crew, in their successful effort to bring the boat to the surface under these trying conditions, displayed the most perfect nerve and coolness. The orders of the captain of the boat were ably executed by the sub-lieutenant and crew, and to this alone can their return to the surface, after several moments at an excessive depth, be attributed.

Though the captain of the boat was found guilty of default, we have little doubt this has been overlooked after the Commander-in-chief's signal to the fleet at Portsmouth, which in part ran: "Their pluck and devotion to duty were aptly described by the President of the Court, in his report to the Admiralty, as worthy of the best traditions of the service."

There was no war-tingle in the veins of this crew to excite them to deeds of valour, but merely four-o'clock-in-the-morning courage. The signal of praise was well deserved, and it is one the submarine service of this country is proud of.

It is a well-known fact that the Powers who might become our enemies would endeavour to drop mines off our principal ports in time of war, a form of offence that we must be prepared in every way to resist.

The future successful naval tactician will not be the one who places his fleet in the most advantageous position for gun-fire but

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the one who can force his opponent over a skilfully mined area. It may, however, be a great disadvantage to both sides if too many mines are laid, as after a time nobody knows where they are, and the danger to shipping is serious, as shown by the many ships that have struck mines with disastrous consequences (see Plate 97).

"One of the floating mines * which were so often reported by steamers passing between Chefoo and Neuchang was observed by the China Navigation Company's steamer 'Wuchang' in latitude 39° 9′ N., longitude 120° 50′ E., and on sending a boat to examine it, found that it was attached by a wire rope to an anchor. The mine was taken in tow by the steamship, and eventually brought into Chefoo harbour, secured to the ship's rails. In considering the great danger involved, the steamer's agents consulted the captain of the U.S.S. 'Frolic,' who consented to sink the mine by gun-fire; this was accomplished in a couple of rounds from the 'Frolic's' guns." A drifting mine destroyed by American naval officers is shown on Plate 96. In considering these dangers, international conferences can perhaps decide the question of restricting the use and location of submarine mines; and no doubt the second Conference assembled at the Hague will fully consider the whole question of making belligerents recompense for all losses to neutral shipping when floating mines of the contact type are extensively used. The principle of having a permanent international Court of Arbitration at the Hague is distinctly sound, but in practice how can the Court in some dispute enforce an adverse verdict on a wealthy nation, even if it has a limited armament? Because no answer to this question is as yet forthcoming we may be assured that all the great Powers will instruct their representatives at the second Hague Conference to pledge themselves to nothing but issues of minor importance, as at the first Conference.

* Extract taken from the *Daily Graphic*.

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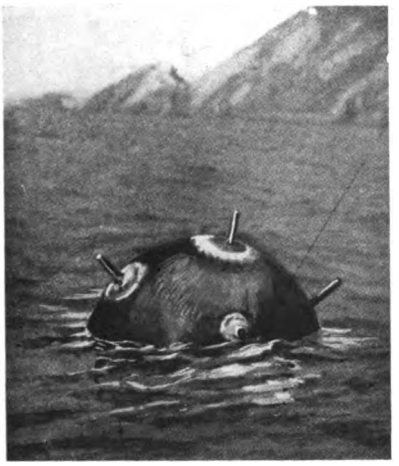

Plate 96.—*A RUSSIAN ELECTRO MECHANICAL MINE FOUND DRIFTING IN CHEFOO HARBOUR AND DESTROYED BY AMERICAN NAVAL OFFICERS.*

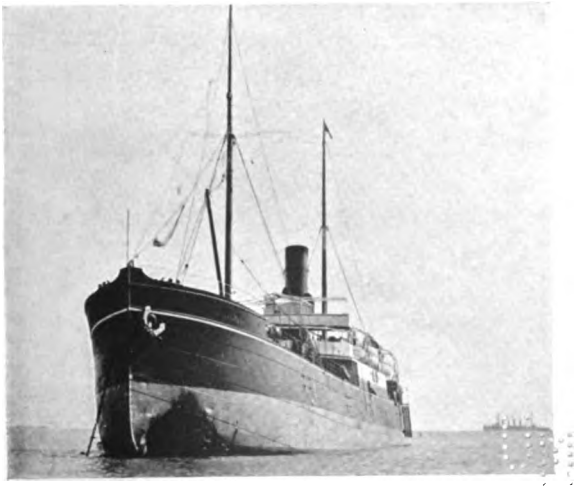

Plate 97.—*BRITISH S.S. "KASHING" AFTER STRIKING A JAPANESE MINE, 1905.*

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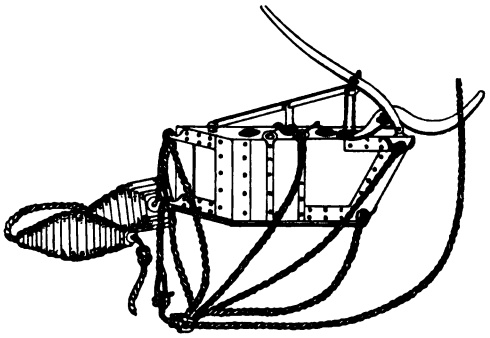
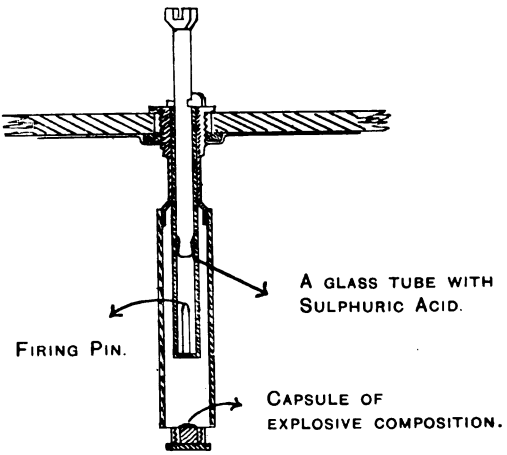
FIG. 78.



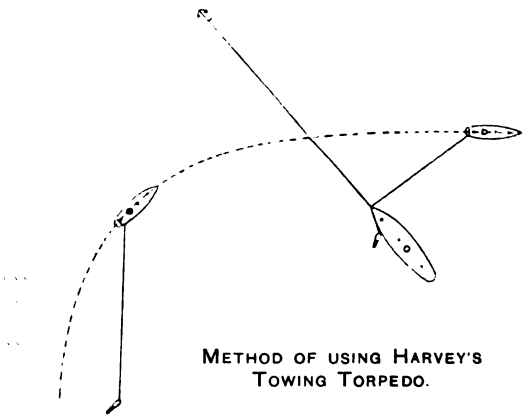
HARVEY'S TOWING TORPEDO.

FIG. 79.



FIRING BOLT
FOR
HARVEY TORPEDO.

FIG. 80.



METHOD OF USING HARVEY'S
TOWING TORPEDO.

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CHAPTER XXII.

THE EVOLUTION OF THE LOCOMOTIVE TORPEDO.

TORPEDOES.

THE first torpedo apparatus supplied to ships in the British Navy for use when in motion was the joint invention of Captain John Harvey and Commander Frederick Harvey.* It consisted of a sheet-copper case of the shape shown on Fig. 78. This was of two sizes, one to contain 76 lbs. of rifle fine-grained powder, and the other 27 lbs. of a similar explosive. Gun-cotton could also be used if desired. In order to manœuvre with this weapon from a ship a speed of about 6 knots was required, and the torpedo had to be towed, as in Fig. 80. The form was similar to what is commonly known as an otter, used for fishing purposes, and when towed at a distance of 150 yds. or so always diverged from the ship's quarter at an angle of about 45°. The explosive was arranged so as to be fired by a metal bolt K (Fig. 79). On coming into contact with the bottom of a ship the force of impact was sufficient to drive this bolt against a pin O, thereby fracturing a glass tube T containing sulphuric acid. On this taking place the acid was allowed to fall on a chemical mixture, and at once caused it to break into flame, which ignited the fuse, that in turn fired the explosive. The safety shearing-pin S was arranged to withstand a pressure of from 30 to 40 lbs. before fracturing in the large torpedo, and 15 to 20 lbs. in the smaller size. As these towing torpedoes did not require any very special fittings, they were particularly suitable for working from any class of ship, and were undoubtedly a most formidable weapon when the attacking vessel could be manœuvred with sufficient skill to bring one of them into contact with her opponent, either at anchor or under way. This required a

* Full details of using these torpedoes are given in *Harvey's Sea Torpedo*, published 1871, London.

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large amount of practice to accomplish and much care in working the brake arrangements, etc. However useful these weapons might have been, they were never tried on active service in our navy, and after a brief career were superseded by a far more efficient weapon, the development of which will require some attention.

The locomotive torpedo is undoubtedly the embryo modern submarine. The success obtained with this weapon during the last two decades has done more to solve the problems of submarine navigation than all the efforts before its introduction; but for such a masterpiece of man's ingenuity the submarine would probably be in the same condition as where Fulton left it. Not only has the architecture of the submarine benefited by the torpedo, but, to use the words of the late Admiral H. J. May, in almost his last contribution to a naval work, "it is the combination of the submarine and the torpedo that is so valuable; but for the Whitehead, the submarine would remain an interesting toy and but little more."

The origin of the now well-known weapon was the invention of Captain Luppis, formerly in the Austrian Navy. This officer offered his Government a self-propelling floating torpedo, in shape much like a boat, to be driven by steam or clockwork mechanism, and directed from a base by guiding lines attached to the rudder (Plate 98). The foremost part was filled with gunpowder, and the explosion was effected by means of a pistol placed in the fore-end of the torpedo, the trigger of this pistol being in communication with a movable blade at that end. The Austrian Government, whilst fully recognising the importance of this invention, were of opinion that in its crude condition it was unworkable without some good form of motive power and a better system of guidance. Captain Luppis sought the advice of the manager of an engine factory at Fiume, named Mr. Robert Whitehead. This able engineer went into the rough plans of the Austrian captain and brought much mechanical genius to bear in working out the idea. He soon saw that in the original form the invention would have little or no value, as it was too difficult to control a weapon of this description for any great distance from a base, particularly a moving one such as a ship; therefore the first suggestion was modified, and Mr. Whitehead experimented with various models in which the steering and propelling devices were carried inside the shell, the whole apparatus being quite self-contained.

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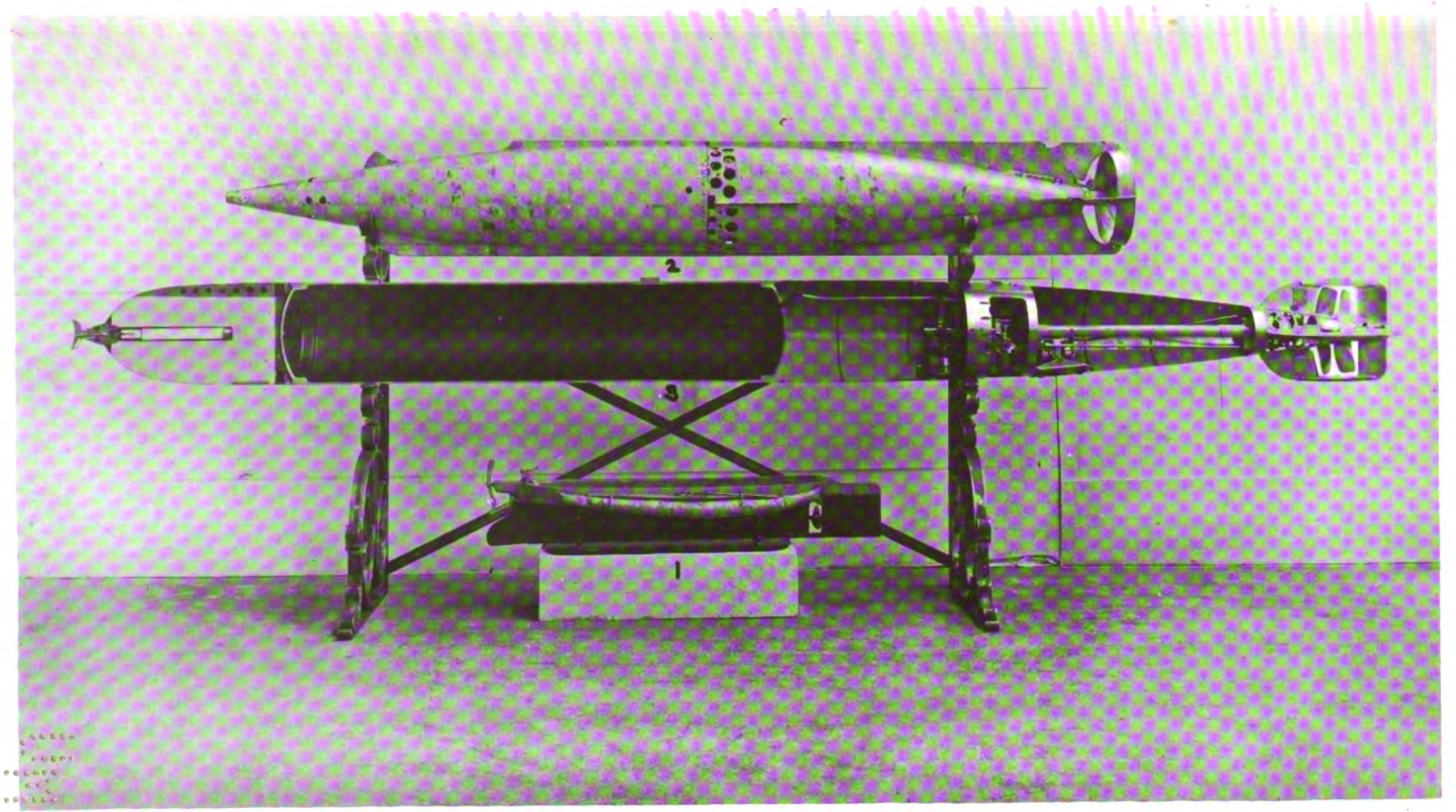

PLATE 98.

1.—Model of CAPTAIN LUPPIS' first Locomotive Torpedo, 1867. 2.—16-inch Torpedo: Charge, 76 lbs. of Gun Cotton; Range, 400 yards; Speed, 8 knots, 1870.
3.—14-inch Fiume Torpedo fitted with Gyroscope; Charge, 78 lbs. of Gun Cotton; Range, 1,000 yards; Speed, 31 knots, 1907.

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After two years of incessant labour, the first Luppis-Whitehead torpedo * was produced (Plate 98).

The Austrian Government decided to enter into a series of experiments with this weapon. It then consisted essentially of the following parts :—

1. The head, which contained the explosive charge of 18 lbs. of dynamite.

2. The air-chamber, which contained the motive power of compressed air charged to a pressure of 700 lbs. per square in. This was the maximum pressure the boiler plates forming the chamber would stand.

3. The engine-room, containing the propelling machinery. This compartment terminated in the tail and screw propeller. The total weight was 300 lbs. and a speed of about 6 knots was obtained. The Government admitted the possibilities of this weapon, but for financial reasons did not purchase the invention for their exclusive use, and therefore other Powers were invited to witness further experiments.

The experience gained during these trials showed that several improvements might be made with advantage. The air-chamber was re-designed, and then made out of one solid piece of iron instead of boiler plates; this allowed the air-pressure to be raised from 700 lbs. to 1200 lbs., giving a range of nearly 1000 ft. These first torpedoes were extremely erratic in their depth-keeping qualities, but in 1868 a considerable advance was made in this respect by the introduction of the present balance-chamber mechanism.

A year later the British Admiralty had their attention drawn to the progress that was being made with the new invention, and instructed the Commander-in-chief on the Mediterranean station to appoint a Committee of officers to investigate this weapon. A visit was made by them to Mr. Whitehead's works at Fiume, in August 1869. The officers were satisfied with what they saw, and reported favourably on the invention, with the result that Mr. Whitehead was invited to bring two torpedoes and a discharging apparatus to England for a series of more extended experiments.

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* From an historical point of view it is to be regretted that this torpedo has not kept to the name it was first known by, as Mr. Whitehead would probably have never had his attention drawn in this direction but for the Austrian captain, and the idea undoubtedly germinated with the latter.

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The first two torpedoes were brought over towards the end of 1870, and were of the following dimensions:—

	Length.		Range.	Diameter.	Depth.	Charge.
	Ft.	Ins.	Ft.	In.	Ft.	
Large torpedo . .	14	0	3000	16	5-15	67 lbs. gun-cotton.
Small torpedo . .	13	10½	2000	14	5-15	18 lbs. dynamite.

They were divided into four main compartments:

1. The head.
2. The adjustment chamber containing the secret.
3. The air-chamber and engine-room.
4. The tail and propellers.

The air-chamber was made of wrought iron, slightly thicker than the other parts of the shell; a vertical fin on top and bottom extended about two-thirds of the whole length, these kept the torpedo upright when passing through the discharging frame. Another Committee was appointed, and a series of trials took place at Sheerness from H.M.S. "Oberon."

The chief points the inventor claimed were:

1. The Luppis-Whitehead torpedo, on being discharged from a submerged tube or frame, would keep a moderate depth-line during the whole run. The depth-keeping mechanism could be adjusted for any depth between 5 and 15 ft.

2. On due allowance being made for deflection, the torpedo would run straight when discharged from a stationary or moving vessel.

3. On striking an object, the impact was sufficient to ignite a percussion-cap, which then exploded the head.

4. The speed and distance travelled were capable of accurate adjustment.

5. A safety wedge was provided, which made the pistol quite safe whilst handling the torpedo before being discharged.

The torpedoes were severely tested, under various conditions, when firing from the submerged bow tube fitted in H.M.S. "Oberon" and from frames attached to steamboats, over one hundred runs being made with, on the whole, satisfactory results. The Committee considered that if the Government decided to adopt this invention,

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many small improvements could be made to make the weapon fairly reliable. They finally submitted a strong report, in which the last paragraph stated "that it was unanimously their opinion that any maritime nation failing to provide itself with submarine locomotive torpedoes would be neglecting a great source of power both for offence and defence."

The Government, acting with most unusual promptitude, at once came to terms with Mr. Whitehead, and bought the right of manufacture for £15,000, stipulating for the following conditions:—

1. A select number of officers to be trained in the then jealously-guarded secrets of the invention.
2. The right of manufacture in England.
3. To be kept fully advised of all improvements.
4. The privilege of using all such innovations.

Experiments were subsequently carried out to ascertain the damage that could be done when firing the torpedo at a ship protected by wire nets. The formula then in use for determining the radius of the destructive effect of a gun-cotton charge was

$$R = \sqrt[3]{32 \times 67}$$

This gave approximately the distance the nets were to be hung from the ship's side. The wooden corvette "Aigle" was detailed for these trials and protected by a stout net, 80 ft. by 12 ft., constructed so as to be able to stop the torpedo; this net was suspended from spars rigged out from the upper deck, with the lower end heavily weighted. Chains were placed under the ship to assist in raising her if needed, and she was anchored off the Medway for the experiments.

Strange to say, the first torpedo was not keen on being muzzled, and just missed the edge of the nets, hit the ship under the quarter, and fully demonstrated the destructive powers of the new weapon by sinking her promptly in the mud. The war-head contained 67 lbs. of gun-cotton, and knocked a hole in the bottom 20 ft. by 7 ft. A smaller torpedo, containing 18 lbs. of glyoxaline, was fired at the nets and blew them with great violence towards the ship's side, but did little damage to the hull. This led to the introduction of the hanging net for protection of ships when lying in harbour against a torpedo attack. Until the Russo-Japanese war of 1904–5, the net began to be looked upon as an unnecessary encumbrance, and some navies even abandoned its use altogether. A minority of British officers,

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however, clung persistently to this protection, and, having a strong supporter* in a high position, the nets remained in the British ships. The wisdom of this ruling of the Admiralty has been amply demonstrated by the negative results the Japanese torpedo craft have attained in more than one attack on the Russian ships protected with this form of defence. We may now confidently expect a reaction in favour of net protection.

The Royal Laboratory, Woolwich, was selected for the manufacture of Whitehead torpedoes, and soon we had various types introduced into the naval service

A table of the first efforts is worth noticing in comparison with that given on page 299.

Range in Yards.	Whitehead Fish Torpedo.			Woolwich Fish Torpedo.
	14 ft. long, 16 in. maximum diameter. One screw.	14 ft. long, 16 in. maximum diameter. Two screws.	14 ft. long, 14 in. maximum diameter. Two screws.	14·5 ft. long, 14 in. maximum diameter. Two screws.
	Knots.	Knots.	Knots.	Knots.
200	..	..	20	25½ †
250	9½	..	..	..
300	..	12½	19½	24½
400	8	..	18	23
600	..	11	..	20
750	..	10½	..	..
800	6	..	16½	16
1,000	..	7	..	14

In 1877 a new design of torpedo was got out, the long fins seen in the 16-in. were abandoned, and a series of 14-in. torpedoes were produced. In this country modifications have been made from time to time; each large departure from the previous design has led to a nomenclature of marks as shown in the following table.

* Now Vice-admiral Sir John Durnford, K.C.B., D.S.O., then fourth Sea-lord of the Admiralty.

† Pressure of air in engines varies for distance and speed from 40 atmospheres to 14 atmospheres.

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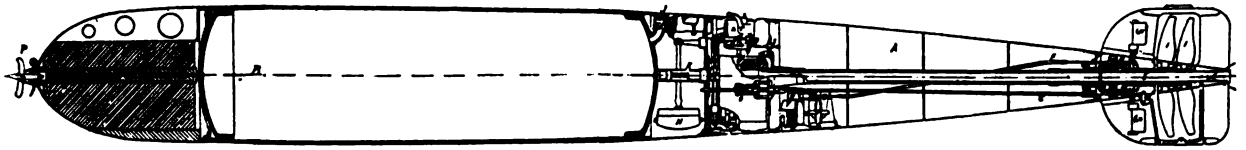

FIG. 81.—*LONGITUDINAL SECTION OF 18-INCH MARK II. 5 METRE WHITEHEAD TORPEDO. SPEED, 30 KNOTS AT 1,000 YARDS, 24 KNOTS AT 1,500 YARDS.*

P.—Plunger or Striking Rod.
g.—Safety Pin.
G.—Gun Cotton Charge.
D.—Priming Charge.
R.—Air Flask.
J.—Charging Valve.
K.—Hydrostatic Valve.
H.—Pendulum.
M.—Engines.
N.—Mechanism for controlling submergence and stoppage.
S.—Submergence Valve.
X—Valve Case.
Y.—Air Lever.
O.—Immersion Servo-Motor.
L.—Pressure Regulator.
V.—Gyroscope.
T.—Spring for Starting Gyroscope.
U.—Direction Servo-Motor.
F.—Controlling Rod to Vertical Rudders.
E.—Propeller Shaft.
B.—Shaft Gearing.

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Type of Torpedo.	Date of Manufacture.	Length.		Weight.	Speed in Knots at 600 Yards.	Range in Yards.	Charge of dry Explosive carried in the Head.
		Ft.	Ins.	Lbs.			Lbs.
14-in. R.L. Mark I, I and I.	1876–82	14	6	525	18·0	600	32
,, ,, ,, II and II	1876–82	14	7	575	19·0	600	34
,, ,, ,, III . .	1882–83	14	7	578	20·0	600	34
,, ,, and Leeds Mark IV and IV	1883–87	14 14	6 11·85	630 674	23·0	600	60
14-in. R.L. Mark V and V .	1885–87	14 14	6 11·85	654 679	25·0	600 750	60
,, ,, ,, VI and VI	1886–87	14 14	6 11·85	648 682	25·0	600	60
,, ,, and Leeds Mark VII and VII	1887–88	15	0	707 708	27·0	600	70 65
14-in. R.L. and Leeds Mark VIII	1888–93	15	0	708½	26·0	600	65
14-in. R.G.F. and Leeds Mark VIII	1893–94	15	0	708½	26·3	600	65
14-in. R.G.F. and Leeds Mark IX	1892–99	15	0	726	27·63	600	77
14-in. R.G.F. and Leeds Mark X	1897–1903	15	6	761½	30·0	800	77
14-in. Weymouth Mark I .	1898–1901	14	11·56	741	30·0	800	77
,, Fiume Mark I . .	1876–79	14	6	529	17·5	600	26½
,, ,, ,, II . .	1876–79	14	6	594	20·0	600	30
,, ,, ,, I . .	1876–79	13	3	554	21·0	600	58
,, ,, ,, IV . .	1885–86	14	9	660	23·0	600	58
12-in. Baby	..	9	6	275	21·0*	300	26
14-in. Schwartzkopf or Berlin	..	15	0	602	23·5*	440	31
18-in.R .G.F. Mark I and I.	1890–92	16	7·4	1,213	30·15	800	188
,, ,, ,, II and II	1892–94	16	7·4	1,227½	30·43	800	188
,, ,, ,, III . .	1894–95	16	7·4	1,213	30·44	800	171
,, ,, ,, IV . .	1895–1902	16	7·4	1,218	30·6	800	171
,, ,, Short . .	1890–95	12	5	861	28·81	800	85½
,, Fiume Mark I . .	1890–91	16	7·4	1,136½	30·0	800	198
,, ,, ,, II . .	1891–95	16	7·43	1,136	29·45	800	187
,, ,, Short . .	1890–93	12	0·74	856	28·51	800	88

* Speed for 300 and 440 yards.

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About 1894 the Royal Laboratory turned the manufacture of the torpedoes over to the Royal Gun Factory, which explains the letters R.L. and R.G.F. in the table; also it can be seen there are now two distinct sizes of torpedoes used in H.M. service, the 14-in., for use in ships, steamboats, and torpedo-boats, and the 18-in. for all battleships, cruisers, destroyers, etc. The latter is termed 18-in. for convenience; its actual diameter is 17·71 in., and is similar to the 45-centimetre type used by the United States and most other navies, the length being about 5 metres.*

The short 18-in. torpedo was designed for use from dropping gear in boats, as the 18-in. long was too weighty. It was never a success, and is now obsolete. In the 18-in. Mark II and III, bronze after-bodies were originally fitted, but did not prove satisfactory, and in most cases have been replaced by steel. With the 14-in. Mark VIII, R.G.F., and 18-in. Mark IV, three-bladed propellers were introduced for the first time, and, at a later date, four-bladed were adopted. Most nations are now ranging up their torpedoes to 4000 yds. with a maximum speed of 36 knots for at least 1000 yds.

A few words on the internal economy of a modern Whitehead may be of interest to non-experts. Let us take the Mark II 5-metre torpedo (Fig. 81), as used in the United States, and run through the chief characteristics, which are common to nearly all Whitehead torpedoes. The torpedo is now divided into the following sub-divisions:—

1. The head.
2. Air-chamber.
3. Balance-chamber.
4. Engine-room.
5. Buoyancy-chamber.
6. Tail and propellers.

The Whitehead is supplied with a practice or collision head, made of thin copper and filled with water, for use when exercising at targets or firing against other ships in manœuvres. In these practices an indicating light is placed inside the collapsible head, filled with phosphide of calcium; this breaks into flame and smoke on coming into contact with water, and, when the torpedo is stopped, shows its position in a fairly efficient manner.

A war-head is also provided containing wet gun-cotton. To detonate

* 1 metre = 3·28 ft.

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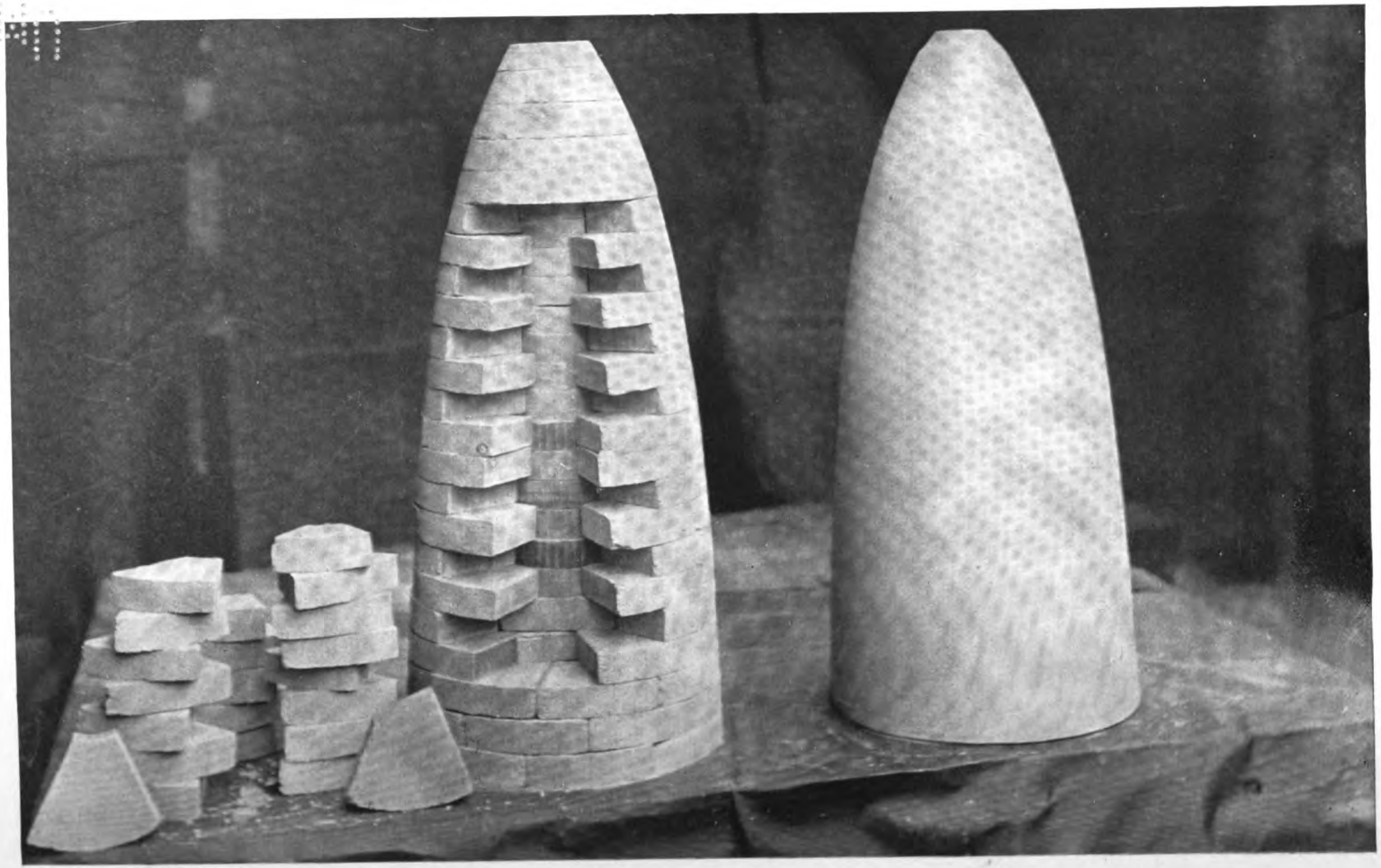

PLATE 99.—*SOLID AND BUILT-UP WARHEADS FOR 18-INCH LOCOMOTIVE TORPEDOES.*

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this a pistol is fitted in the extreme end. On striking the under-water portion of a ship the impact forces a roughened, hardened steel point into a fulminate of mercury detonator, which detonates a dry primer and causes explosion of the whole war-head into a gaseous mixture some 3000 times its own volume.

Three arrangements are provided to keep the pistol safe in handling; the first is a pin, which prevents the other safety arrangements from working; the second is a small fan threaded on the striker rod which, when screwed home, takes against the metal body of the pistol and prevents the striker being forced into the detonator; the third is a phosphor-bronze screw, which screws through the body of the pistol into the striker, thus locking the two together. Before the torpedo is fired, the safety-pin must first be removed. On the torpedo entering the water the fan is unwound by the action of the water on its blades, and when the torpedo has travelled about 100 yards, the fan is fully unwound, leaving the striker quite free, except for the shearing pin. On the torpedo striking an object, the force of impact sheers this pin and drives the point of the striker into the fulminate of mercury detonator.

The war-head was formerly built up of slabs of gun-cotton, but recently this method of stowing the gun-cotton has been considerably improved upon. The damage done by the Japanese torpedoes (as shown in Plates 102 and 103), though considerable, was less than what was generally expected. This, no doubt, was largely due to the manner of building the war-head, also to the centre of gravity of the charge being at some distance from the ship's side when it was actually exploded.

A new departure has been made by the National Explosive Company in the manufacture of gun-cotton, as hitherto large charges (Plate 99) have been built up of segments of no greater thickness than 2 in., or of greater weight than 8 lbs. or 9 lbs. Briefly, the new features introduced are, the working up of gun-cotton pulp in such a manner that air is completely expelled, while the mass is worked together so as to produce a cohesive and homogeneous block. By previous existing processes the air has not been removed; the cavities in which it rests are naturally made smaller by pressure, but when the pressure has been moved it is contended that they expand again rendering the block spongy or laminated; the consequences of

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this is that detonation is often not complete and has a diminished destructive effect when the charge is fired.*

Other advantages claimed by the patentees of this process are: no space is wasted, as with built-up charges; the saving in this respect, and the higher density obtained, enables 25 to 27 per cent. more gun-cotton to be got into the same size war-head than under the old method. The uniform density obtained ensures the complete detonation of the entire mass, which is an important feature where the charge has to be kept within the limits of a war-head for an 18-in torpedo.

Any improvements that can be made to increase the destructive effect of the war-head are of vital importance; and, though not advocating any large departure from the size of the present charge, I am confident that a much more efficient war-head can be produced on the lines indicated by this enterprising company.

Contrary to all expectations of those who often held up the torpedo war-head to ridicule as being dangerous to the user in small surface craft, there was not, I believe, a single case of a war-head prematurely exploding in the whole Russo-Japanese war,† therefore the confidence placed by torpedoists in these weapons was fully justified.

The air-chamber comes next to the head, containing the motive power of compressed-air at a pressure of 2250 lbs. to the square in. This chamber is made of the finest steel procurable, worked from a solid ingot into a cylindrical shell varying from 0·275 to 0·365 of

---

* Interesting comparative tests have been recently made in the United States between war-heads made of solid blocks as against the built-up gun-cotton charge. Two improvised counter-mine cases of equal structural strength were prepared; in one a solid block charge was fitted measuring 17½ in. in diameter and 36 in. long, with an axial hole of 2 in. in diameter, the weight of dry gun-cotton being 363·5 lbs.; in the other case a built-up charge of same weight was placed. The mines were moored on the bottom in 3 fathoms of water and then fired, the explosive effect being obtained by measurement of the various columns of water thrown up from photographs taken by three cameras placed 670 feet from the mines. The heights were determined as follows:—

The solid charge	454 feet.
The built-up charge	315 „

This experiment indicates very clearly the superiority of the solid charge, and when it is remembered that 27 per cent. more gun-cotton can be placed in an 18-in. war-head than by the built-up method, the advantage is still greater.

† Russo-Japanese war, 1904–5.

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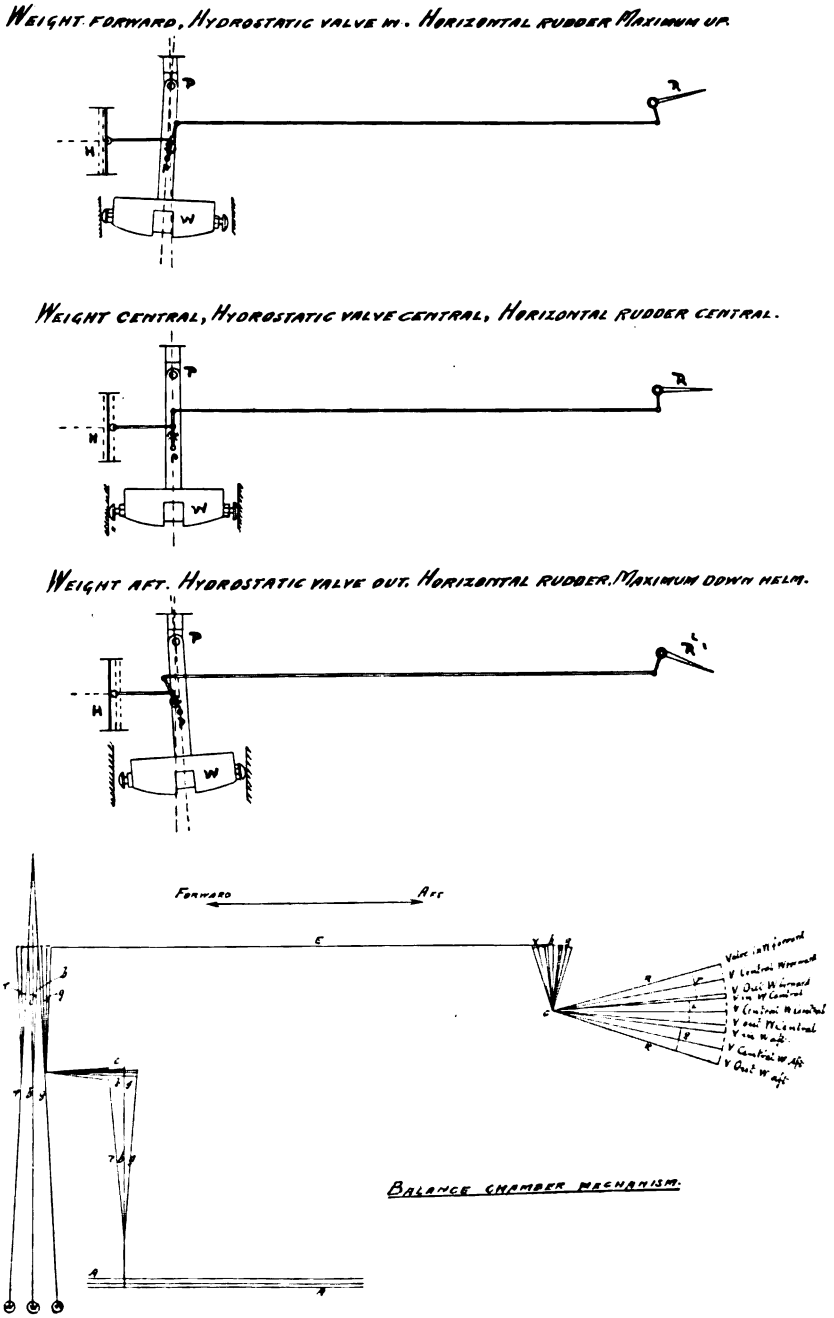

FIG. 82.—*THE ONE-TIME "SECRET" OF THE BALANCE CHAMBER SHOWN DIAGRAMMATICALLY.*

H.—Hydrostatic Valve.
R.—Horizontal Rudder.
W.—Pendulum Weight.
P.P.—Pivots.

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an inch in thickness, the cylinder being hermetically closed with patent self-sealing, cup-shaped ends, manufactured also from the finest steel. Attached to the air-chamber is the balance-chamber containing the depth-controlling mechanism, first known in early torpedoes as "the secret," and kept highly confidential for a number of years, until it was suddenly realised that everybody knew it. Since then no attempt has been made to keep the modern Whitehead confidential.

The secret or balance-chamber contains the mechanism (Fig. 82) for keeping the torpedo at the depth it is adjusted to run at; a movable disc is fitted in the shell or door of the balance-chamber and made water-tight by an india-rubber joint, the disc being kept "out" by a spiral spring acting on it from the inside; this can be adjusted to equal the pressure the water would exert at various depths. When the torpedo is above the depth, the hydrostatic disc or valve is "out," if below its depth, the valve is forced "in." At the set depth the valve is in equilibrium, that is, the pressure due to the depth of water is equal to the pressure exerted by the spring. In conjunction with this hydrostatic valve a pendulum weight works according to the inclination of the torpedo, a series of levers connect the valve and weight to a small air-engine, called the "servo-motor," introduced in 1876. With a half-ounce pull or push on the slide rod of the motor, the piston is capable of lifting 180 lbs. This increase of power is very necessary when it is borne in mind that the torpedo has to be given up or down helm when travelling at the rate of more than 50 ft. per sec. At this speed only a slight amount of rudder angle has to be used, but to produce it the extra power is provided. The balance-chamber mechanism is so arranged that if the torpedo is above the depth it is adjusted for, the valve being "out," the horizontal rudders give down-helm, and if below its set depth, the rudders give up-helm. Now, to modify this action, the pendulum weight is introduced to act according to the inclination of the torpedo and decrease or increase the amount of rudder, due to the hydrostatic valve. The weight can act with the valve or against it, according to the inclination and position of the torpedo with regard to set depth. By this combination of hydrostatic valve and balance weight a very even depth-line is maintained. Fig. 82 shows the chief positions the horizontal rudders can take up.

Next to the balance-chamber comes the engine-room, containing

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the propelling engines, the servo-motor for working the horizontal rudders, and the counter-gear for making the range adjustment.

Projecting through a slit in the shell is the air-lever, which, on firing the torpedo, is thrown back by a tripper on the discharging apparatus; this opens the starting valve and allows the compressed air to come from the air-chamber into the main supply pipe. On firing from above water, a delay-action valve,* worked by a small flap projecting above the shell, is provided. In this valve the air is made to filter slowly through to prevent the propellers revolving in the air at a high rate, owing to there being no water to act as a resisting medium.

On striking the water the air-flap is thrown back; the full pressure of air then passes to the reducer, a valve specially devised to bring the pressure down to that for which the engine is designed to work at. By making use of reduced-pressure air a much lighter engine can be used, and also a uniform speed is obtained during the whole of the run. The reducer adjustment allows of a long range at a moderate speed, or a short run at maximum speed. The engines are mostly constructed by Messrs. Brotherhood, and are of the three-cylinder type, of under 4 in. in diameter, and the length of stroke is about 3 in.; they develop 56 I.H.P. The engine drives a single shaft to which is fixed the after-propeller. Intermediate bevel-wheel gearing works a sleeve in the opposite direction, to which is attached the foremost propeller, usually made to revolve in a clockwise direction, whilst the after one rotates the opposite way.

These propellers are arranged to balance each other exactly, the after one, being farther from the turning-point of the torpedo, is consequently made the smaller of the two.

Abaft the engine-room is the thin steel compartment named the buoyancy-chamber, containing the tubes through which pass the main-propeller shafting and the diving-rod for working the horizontal rudders. In the forward lower end is placed the gyroscope apparatus. This chamber provides, in addition to a small amount of floatability from the balance-chamber, the buoyancy of the torpedo. With the air-vessel charged to action pressure of 2250 lbs. to square inch plus a war-head, the buoyancy in modern designs is a negative quantity. However, for exercise a few pounds of positive buoyancy are insisted

* This delay arrangement is not required in submarine boats or ships fitted with submerged tubes, as the torpedo starts in water.

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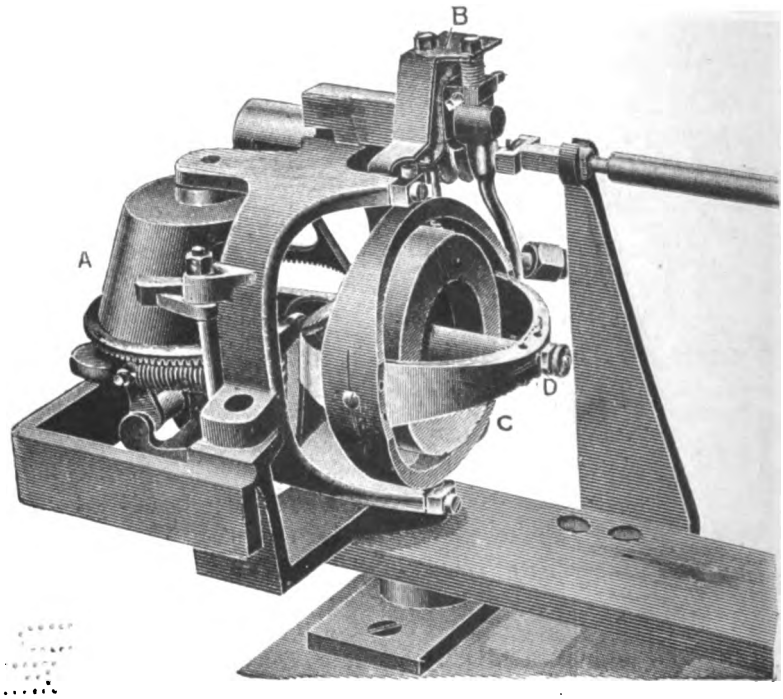

FIG. 83.—*THE GYROSCOPE APPARATUS.*

A.—Cone with Toothed Rack.
B.—Air Valve.
C.—Heavy Flywheel suspended in Gimbals.
D.—Adjusting Nut and Counterpoise.

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upon to ensure the recovery of the torpedo should a failure occur The amount of air expended during a run weighs several pounds. This provides sufficient buoyancy to usually allow the torpedo to lie horizontally on the surface of the water when the distance set for has been traversed. The smoke from the Holmes light then indicates its position to the picking-up boats. If a live torpedo is fired under service conditions, the torpedo is set to sink. This a useful precaution, to minimise the possibility of any damage to a friendly ship should the torpedo fail to strike the object aimed at.

Attached to the buoyancy-chamber is the tail in which, as previously mentioned, the bevel-wheel gearing for working the foremost propeller off the same shaft as the after one is placed. Horizontal and vertical fins are provided, to which the horizontal and vertical rudders are attached respectively.

The next most important step in the evolution of the torpedo was the introduction of an automatic steering apparatus in 1898–9. The invention was not at first received with much favour in this country, as we had obtained more accuracy with the Whitehead, unprovided with such an arrangement, than probably any other nation.

It is an open secret that a similar instrument was brought to the notice of the authorities at Whitehall by a naval officer, many years before; but at that time it was not considered to our advantage to develop the device; however, once more a new invention was forced upon us, as all nations adopted this apparatus for automatically controlling the direction of their locomotive torpedoes. This apparatus was invented by Mr. L. Obry, of Trieste, who sold his invention to Mr. Whitehead, and the latter then developed it for his torpedo. The instrument is now generally spoken of as the "gyroscope" or "Obry" apparatus, and is placed in the buoyancy-chamber (Fig. 83). This apparatus has got over erratic running, due to deflection of the torpedo on entering the water, dents or damage, particularly in tail, one propeller overcoming the other, due to an imperfect balance, etc.

The gyroscope requires delicate handling, and in skilful hands 95 per cent. of runs should be hits; it is shown clearly in Fig. 83. The apparatus consists of a heavy fly-wheel supported in gimbals, a method that gives the wheel a very delicate suspension, as friction is practically non-existent. The wheel is set spinning by a powerful spring, just as the torpedo passes the tripper on the tube, that

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actuates the air-lever for supplying compressed air to the engine and air-valve of gyroscope. The speed of rotation of the wheel is over 2000 revolutions per minute. At such a high velocity the heavy wheel possesses a directive force constraining the axis of the wheel to always point to the same spot in space. This axis is placed in the longer axis of the torpedo. If the torpedo curves left or right during a run the wheel tends to remain pointing in its initial direction. To the outer suspending gimbal is fixed a small vertical rod, which is made to work a V-shaped attachment to the air-valve; this allows air pressure to pass one side or the other of a piston working in a cylinder in connection with the gyroscope rudders on the vertical fins. This gives starboard or port helm, according to the position of the valve.

Since the general adoption of this apparatus many improvements have been made, and various marks of gyroscopes now exist in most navies. One of the latest in the U.S. Navy is* the Mark II. "This differs from the Mark I gyroscope in that it has its wheel spun by air impulse instead of by a spring, and is thus always ready for instant service without winding; that its parts are so arranged that it can be adjusted in the shop before being put aboard ship, and then will remain in adjustment, being capable of "dis-assembling" for cleaning without disturbance of adjustment; and that the valve mechanism can be readily so set that the torpedo may be either run straight in the direction fired, or else turn through any desired angle to the right or left (up to 120°) after striking the water, before taking up its straight run. This last power enables the commanding officer of a torpedo vessel to stand at the conning-tower with tubes trained on either side, to point his ship at the spot he desires to hit, and then, by electric firing from this position, to discharge torpedoes from all tubes in the ship simultaneously, in such a way that they will run parallel to the course of the ship. With a three-tube boat like the 'Morris' † he could thus discharge three torpedoes running in a danger zone about 100 yds. wide, one on each side of the zone, and the third down the middle of it. The possibilities of a hit under such circumstances are enormous. Many variations of this form of attack are possible."

Some experiments have been undertaken by Rear-Admiral

* Extract taken from the *Journal of American Society of Engineers.*

† U.S.S. "Morris."

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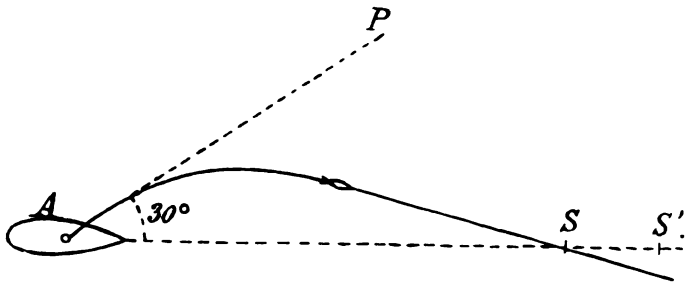

FIG. 84.

FIG. 85.

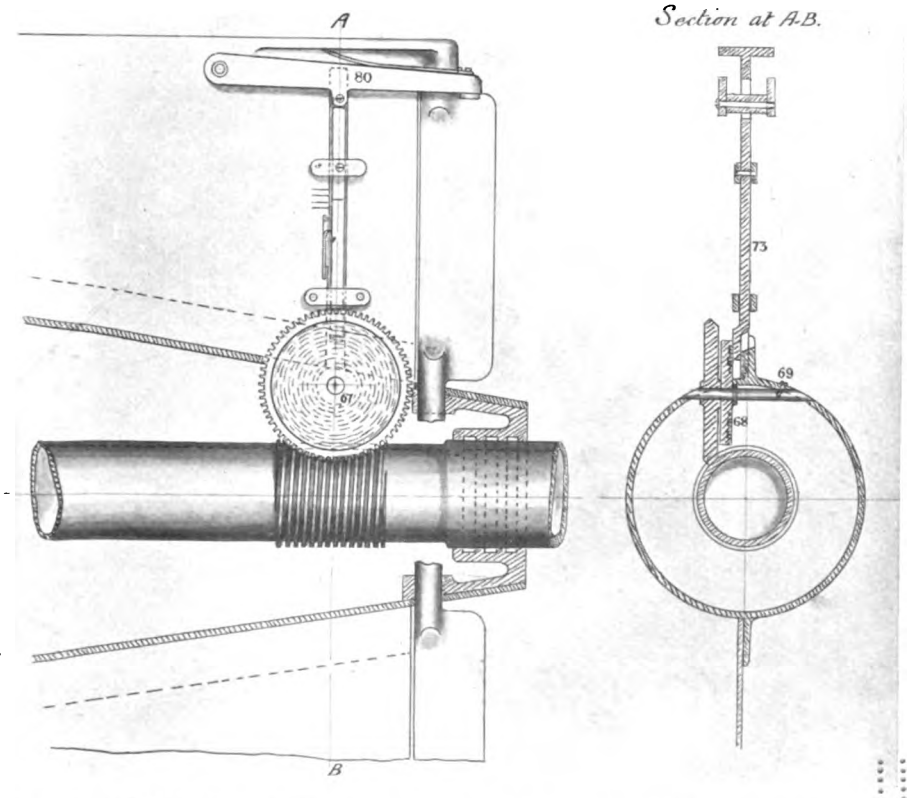

FIG. 86.—*ADMIRAL BOIRESEN'S METHOD OF DEFLECTING A GYROSCOPE.*

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Boiresen, chief of the Norwegian Navy, in connection with this method of controlled fire, who, in summing up his results, writes:

"Adjustable gyroscopes,* that is gyroscopes that can be so regulated as to make the torpedo run in any angle from the line of sight, are hardly used in any navy at the present moment, because the gyroscope is considered too complicated and too fine an instrument for such regulations in the last minute before firing the torpedo.

"But whether the gyroscope is regulated, or constructed to work, in the axis of the torpedo, or to work at a certain angle of, say, 30° from this axis, when the gyroscope is permanently fixed for this angle, this circumstance evidently has nothing to do with the regular working or the complication of the instrument. The gyroscope, in fact, will do its duty without knowing that it is deflecting a torpedo 30° from the line of sight."

Fig. 84 represents a torpedo-boat that fires her torpedo with a gyroscope deflected 30° to the right; the line of sight is AS, the line of launching is AP. With a gyroscope deflected 30°, the torpedo will hit the vessel S only if the vessel just happens to be in the point where the trajectory of the torpedo and the line of sight cross each other; but if the hostile ship is in the point S', the torpedo will miss her.

As a consequence one cannot use deflected torpedoes unless one knows the distance to the ship fired at, and corrects for it, which is out of the question.

To do away with this difficulty, and at the same time have all the advantages that a deflected gyroscope gives, I have devised and tried in the Norwegian Navy, with great success and accuracy, a small and very simple instrument, which makes the torpedo run into the sighting line again as soon as it has been deflected (see Fig. 85). That is to say, it does not follow the dotted line, as Fig. 84, but continues its curve until a point *b* near the sighting line, and then runs into this line; in short, the torpedo is given a "flat" trajectory. This arrangement will give the advantage of being able to fire right ahead (or right astern) from a ship without stem or stern tube, and hit with the same accuracy as if direct firing had been used.

The gyroscope in the torpedo is always, from the very beginning, made to work in an angle of 30° or 45° or 90°, etc., with the axis of the torpedo, and the small attachment does not interfere with the

* Extract taken from the *Journal of the R.U.S.I.*

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ordinary working of the gyroscope, as it does not touch it. The apparatus is placed on the vertical fin (Fig. 86). When the air is turned on the engines as the torpedo leaves the tube the propeller shaft rotates the wheel 67, this being coupled to wheel 68 causes it to turn also; the spiral groove on the latter forces the pusher-rod 73 upward, so that its end will hit the arm 80 and raise it, thus freeing the gyroscope rudder. By loosening screw 69 the wheel 68 may be turned, whereby the starting position of the pusher-rod 73 is adjusted and the apparatus turned.

The following gives a fair idea of the high standard that has to be met before a torpedo is accepted for the U.S. Navy:—

"Each torpedo, with the Obry steering gear removed and the dummy inserted in its place, is to be set for a range of 800 yds., and the depth, speed and deviation taken at that range. The limits of deviation at the 800 yds. target shall not be more than 24 yds. to the right or left of the centre of the target. The limit from the set depth shall not exceed 15 in.

"The above conditions must be obtained with each torpedo in three out of five successive runs. The speed of each torpedo, as determined by the mean of these three runs, must be at least 28½ knots an hour for the range of 800 yds.

"Having successfully met the requirements of the two preceding paragraphs, each torpedo shall have the dummy removed and the Obry steering gear inserted and connected up, and will then be set for a range of 800 yds., and the depth, speed and deviation taken at that range. The limits of deviation at the 800-yd. target shall not be more than 8 yds. to the right or left of the centre of the target. The limit from the set depth shall not exceed 15 in.

"The above conditions must be obtained with each torpedo in three successive runs. The speed of each torpedo, as determined by the mean of these three runs, must be at least 28½ knots an hour for the range of 800 yds.

"Before any torpedo is finally accepted, it shall be run over a range of 1500 yds. with the Obry steering gear in action, and shall show a speed and the ability to maintain a straight course equal to the best results obtained abroad in said particulars for the same type of torpedo when run over a corresponding range.

"The results actually obtained under the above specifications considerably exceeded the requirements, and were as follows:—

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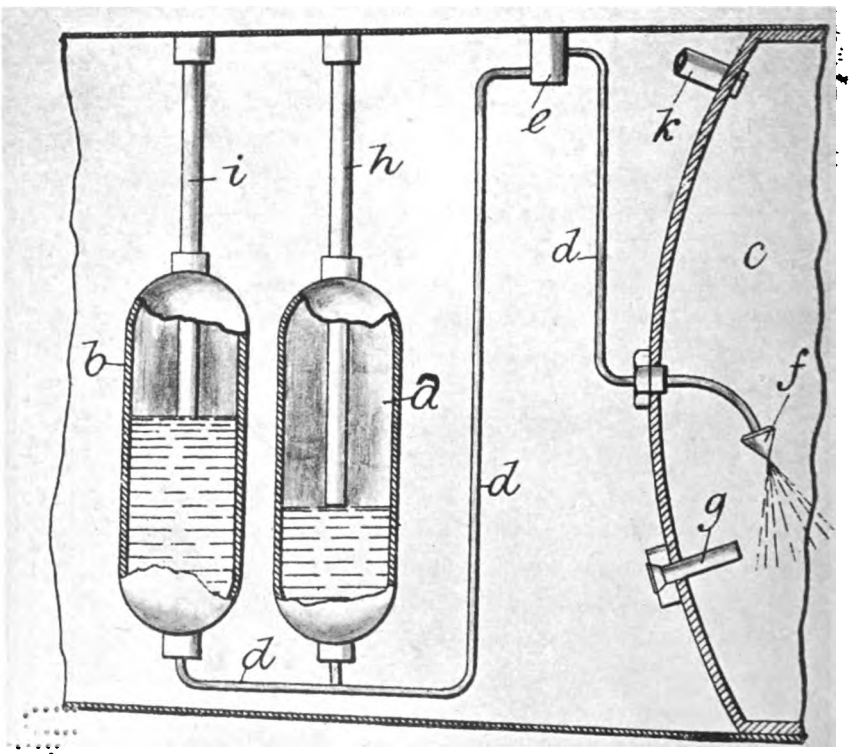

FIG. 87. – *SUPER-HEATING DEVICE FOR INCREASING SPEED OF LOCOMOTIVE TORPEDOES.*

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"Speed at 800 yds. The torpedoes built on these specifications average about 30 knots for the 800-yd. run, instead of the 28½ required.

"Accuracy at 800 yds. At this range the results were well within the limits laid down.

"Speed at 1500 yds. 24 knots was attained.

"Accuracy at 1500 yds. The torpedoes had no difficulty in keeping within 15 in. of the set depth, or coming within 20 yds. of the centre of the target on either side.

"The results given are those actually obtained on the proving ground, firing from a ship at anchor through a net, so that both the speed and the deflection are most carefully and accurately measured. As far as the mechanism of the torpedo is concerned, there is no reason why these results should not be continually repeated on board ship under experienced handling." *

It is now generally recognised by experts that compressed air as a motive power in connection with the Brotherhood engine has almost reached its highest point of development, so much so that every effort is being made to squeeze an extra knot or two out of the present type of torpedoes in the following manner.

The amount of work obtainable from a charge of compressed air, as stored in the air-chamber of a Whitehead torpedo, is capable of being increased by burning inside the reservoir alcohol, petroleum, or other suitable combustible liquid. This raises the temperature of the air, and consequently the volume which it will occupy at a given pressure is increased.

A part longitudinal section of a torpedo at the after end of the air-chamber is shown in Fig. 87:—

"*a* and *b* are two fuel reservoirs having different ratios of air space to fuel space; this arrangement is employed for obtaining a suitable gradation of the fuel supply. *c* is the air-chamber of the torpedo, communicating with the reservoirs *a* and *b* by the pipe *d*. *e* is a valve on this pipe. The initial rate of flow of fuel through the pipe *d* is due to the expansion of the air in both *a* and *b*; but at a desired stage the reservoir *a*, which has a relatively large air space, will have become empty. The fuel supply is then obtained only from *b*, so that

* Extract from *Journal of American Society of Naval Engineers.*

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the rate of feed is then much less than if the whole of the air originally contained in the fuel reservoirs was still driving out combustible liquid by its expansion. Conversely, the initial rate of feed is much greater than if the air space in *a* had not been acting during the early stages.

"The arrangements for ignition are: *f* is a spraying nozzle at the end of the pipe *d*; *g* is the primer or cartridge for igniting the spray; *h* and *i* are the pipes for charging the fuel reservoirs *a* and *b*; *k* is the pipe for leading the compressed air from the chamber *c* to the engine. Before entering the torpedo into the tube the firing device is set and the valve *e* opened so as to equalise the pressure in *c* and *a*.

"As soon as the engine is started the pressure in the air-chamber *c* begins to fall and, in consequence, the air in the space *a* expands, thereby driving combustible liquid through the spraying-nozzle *f*, so that it enters the air-reservoir in a condition suitable for rapid combustion.

"After an appropriate interval the spray is ignited by the firing of the cartridge and the fuel burns fiercely in the compressed air, so that hot air is supplied to the engine through the pipe *k*." *

This device is entirely automatic, is comparatively simple, is absolutely safe, and increased the speed in an American experimental torpedo in which it was tried from 30 to 35 knots, approximately, for the 800-yd. run.† Of course any such marked increase in speed increases the chances of a hit by reducing the time of flight; this device also increases the total distance that it would be possible to make a torpedo run.

Another improvement, as yet only in an experimental stage, is the adoption of a turbine engine for the torpedo; the results obtained so far would indicate that the efficiency of such an engine would be about the same as that of the Brotherhood engine already in use, but where the utility of the device would come in would be in the fact that, with the turbine, advantage can be taken of a degree of superheating of the air which would quite ruin any reciprocating engine. In the near future, a great simplification of the torpedo engine will probably occur by the adoption of the turbine, with a jump in speed

* These extracts are taken from specification No. 25,003 (1904). Sir W. G. Armstrong, Whitworth and Co.

† Figures taken from *Journal of American Society of Naval Engineers.*

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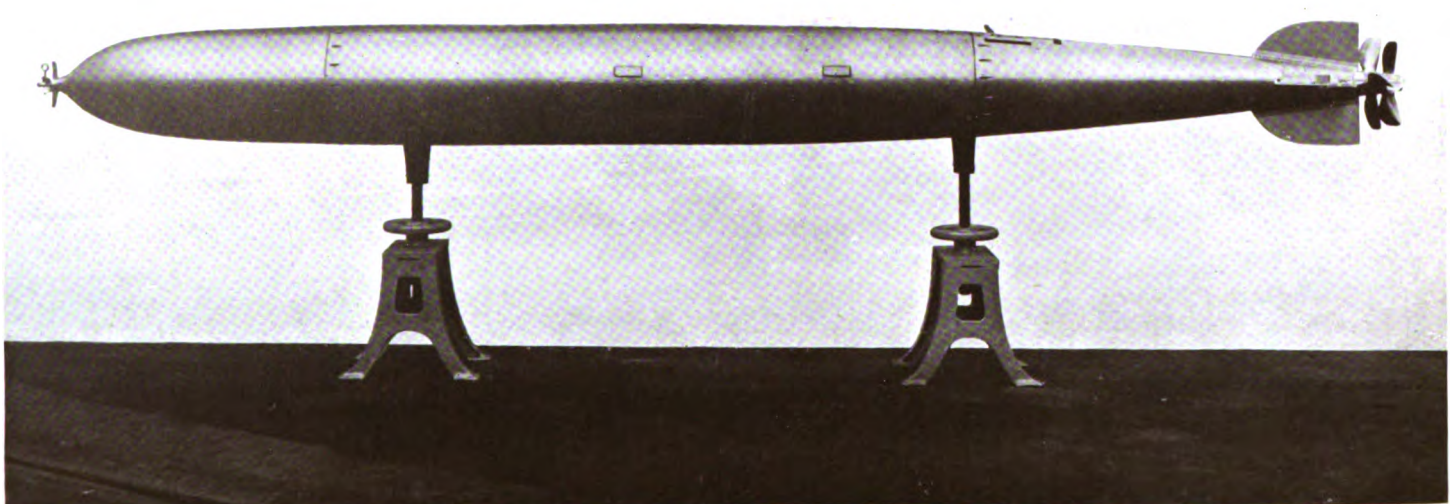

PLATE 100.—*18-INCH R.G.F. MARK IV. TORPEDO.*

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to at least 40 knots * for the 1000-yd. run, and a corresponding increase of range at a slower speed to fully 2500 yds.

A turbine torpedo is now being developed in the United States under the name of the Bliss-Leavitt torpedo. The two new inventions embodied in the design are:

1. A superheating air process.
2. A turbine engine.

On discharging a torpedo from the tube, an alcohol burner is automatically ignited, this superheats the compressed air on its passage to the engine, causing more expansion, increased development of energy, and therefore additional motive power.

This increased power is then applied to the new turbine engine.

The Brotherhood three-cylinder reciprocating engine weighs about 90 lbs., and develops some 56 H.P., whereas the inventors claim that their turbine engine only weighs about 20 lbs. and develops 130 H.P.

Up to the present, Messrs. Whitehead and Co. have not produced a turbine engine superior to their reciprocating type, so we may safely assume that their experiments with the new superheating devices are distinctly promising.

The torpedoes for the British Navy are now made at the Royal Gun Factory, Woolwich, by Messrs. Greenwood and Batley, of Leeds, and at Mr. Whitehead's factory at Weymouth. Recent orders are improvements on the 14-in. and 18-in. shown on Plates 98 and 100. Mr. Whitehead also manufactures torpedoes at Fiume for most of the foreign Governments (Plate 101).

The American Navy has the Whitehead, the Howell and the Schwartzkopf torpedo, but chiefly the Whitehead.

A recent order from the U.S. Bureau of Ordnance consisted of:

1. Fifty 5-metre 45-centimetre torpedoes, with a guaranteed speed of 35 knots for 1200 yds., with a flask pressure of 2250 lbs. per square inch. These are of the same size as the present service torpedo.

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* The *Times* reports that in some experiments undertaken at Weymouth (1907), in presence of representatives from the Admiralty and the Japanese Government, the speed obtained by an 18-in. torpedo fitted with an Armstrong heater for 1000-yd. range was 35·3 knots. This is a gain of 9·3 knots, or 35 per cent., over the 26 knots which can be obtained with a similar torpedo not fitted with the heater for the same distance run. The designers are confident that they can obtain an even higher result by going to a higher temperature. Experiments will shortly be carried out with a view to testing this.

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2. Two experimental 5-metre torpedoes, 21 in. in diameter, which are to run 4000 yds. at a speed of 26 knots, and 3000 yds. at a speed of 29 knots, on a flask pressure of 2250 lbs. These are therefore the same length as the service torpedo of to-day, and about 3 in. greater in diameter.

3. All of the above torpedoes are to be fitted with the modified gyroscope, allowing the curved run.*

Russia has in use the Schwartzkopf and also the Whitehead; the latter is now replacing the former.

Japan has also the Schwartzkopf, but Whiteheads are now employed, and the recent orders are to be fitted with the Obry apparatus. A new type was constructed for harbour defence—length 16 ft., diameter 24 in., charge 200 lbs., air-pressure 2500 lbs. to square in., speed 25 knots, range 3000 yds.—but it proved a complete failure and never left the torpedo works at Fiume.

French service torpedoes are of the Whitehead type, constructed at Mr. Whitehead's factories, or at the French Government factory at Toulon.

	Diameter.	Length.
Long 45 cm.† . . .	17·72 in.	16·40 ft.
Short 45 cm. . . .	17·72 „	13·68 „
Long 38·1 cm. . .	15·00 „	18·86 „
Short 38·1 cm. . .	15·00 „	16·40 „
Long 35·6 cm. . .	14·00 „	16·40 „
Short 35·6 cm. . .	14·00 „	15·58 „

The French naval authorities recently carried out an interesting experiment to ascertain whether the explosion of a torpedo in the vicinity of a submarine exercises any injurious effect upon another torpedo lying alongside the vessel. The submarine anchored off Cape Petet, and the torpedo, containing a charge of 100 kilos (220·4 lbs.) of gun-cotton, was fired at a distance of 50 metres from the submarine, beside which, exposed to the full force of the exploding torpedo, was placed the second weapon. Not the slightest damage was caused by the explosion. And also another experiment was made recently at Cherbourg with a slightly different object. It had been said that a submarine could not fire a torpedo at a short

* See page 307.

† Table taken from *The Naval Pocket-book*, Laird Clowes, 1906.

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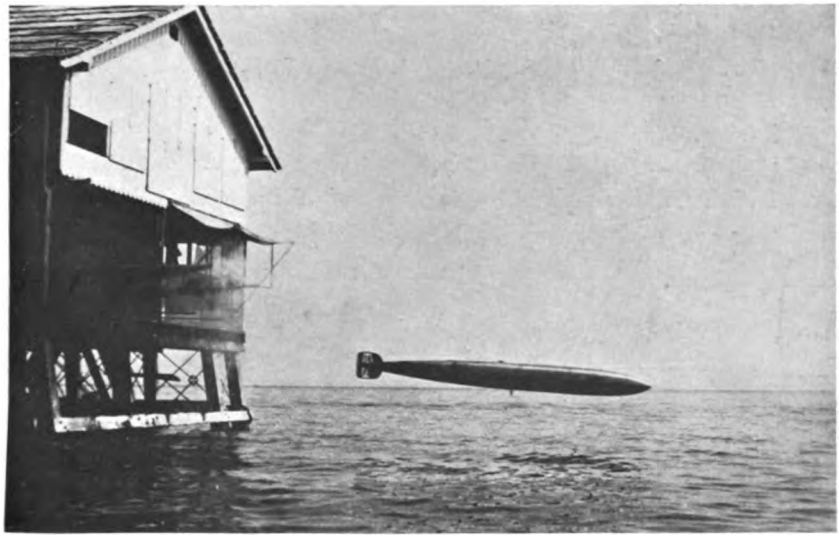
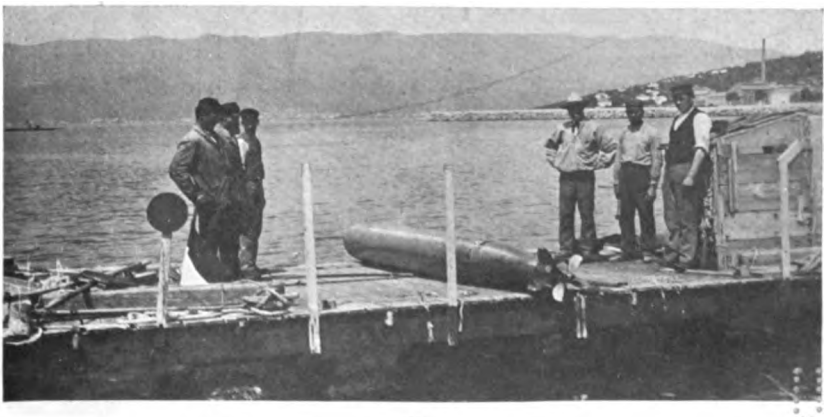


I.

II.



III.

PLATE 101.

This 18-inch Torpedo, adjusted for 2,000 yards, was fired from the above water tube at Messrs. Whitehead's Works, Fiume (I.), and took the water as shown at (II.). On completion of the run, the Torpedo "shut off," jumped clean out of water and landed on the raft marking the 2,000-yard range, as can be seen in (III.). Round disc in III. is centre line of rafts.

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range, because the risk of suffering in the explosion would be too great. Several sheep were placed in the "Naïade," which was under water, and torpedoes were exploded at different distances. As the sheep were not hurt, officers took their places, but the explosions had no effect beyond slightly increasing the pressure on the hull.

The German Schwartzkopf torpedo is made by the firm of that name in Berlin. These are usually constructed entirely of phosphor-bronze, on the lines of Mr. Whitehead's torpedoes. Phosphor-bronze for the whole shell and internal mechanism has many advantages, of which less cleaning required, etc., is not the least. These German torpedoes are of the first workmanship and compare favourably with those of other nations.

Italy uses both Whitehead and Schwartzkopf (phosphor-bronze) torpedoes of the 17·72-in. and 14-in. types.

To discharge a torpedo from a Holland submarine, it is placed into an expulsion tube fixed at the extreme forward end of the boat, opening 2 feet below the ordinary water-line. The tube is placed with its axis slightly depressed; the outboard end is closed by a bow-cap, and this can be raised by suitable mechanism from within. When about to fire, the bow-cap is raised and the torpedo discharged in the usual manner with compressed air. The tube is filled by the water rushing in immediately the torpedo leaves; this compensates for any loss of weight. The bow-cap is closed, and by turning a lever this water is blown into compensating tanks until the tube is quite empty. Two other torpedoes are carried, one each side, on top of the storage batteries, and the same procedure is gone through on firing each. When the last torpedo is fired the tube is full of water, and this is allowed to remain.

In addition, a small tank is provided which carries the volume of water that goes to fill the tube when the torpedo is in it. This is blown into the tube before opening the bow-cap, so as to completely fill it, and allow no change of trim during this operation. After discharging the torpedo and closing the bow-cap, an equivalent volume of water is blown back into the small tank. Compensating tanks are also furnished for blowing water aft as a torpedo is taken forward, etc.

Firing torpedoes when running submerged in a dock was always entertaining as, unless the torpedo ran straight, it usually came into violent contact with the side of the dock. At times our one and only

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18-inch at Barrow caused many anxious moments. Several dives were being made with "No. 5" submarine, and on one occasion the torpedo was fired as usual, the boat brought to the surface, and a little water blown out of the ballast tanks, and conning-tower hatch opened. The launch in attendance was hailed. "Where is the torpedo? Why aren't you after it?" etc. "Haven't seen a sign of it, sir," was the reply. After looking about for some time, more water was blown out of the tanks, the bow came up a little, and there through the dirty, muddy water was our friend, sticking in the tube three-quarters of the way out. When rising to the surface we had noticed the boat took rather longer than usual, but this was attributed to the suction at the bottom, as in dock running we had to go very close to the mud and run in a narrow gut. On returning to the berthing jetty the submarine was secured, torpedo hoisted in, and everything got ready for more dives in the afternoon. The crew were then sent to dinner, and the foreman undertook to put the leaky valve right as soon as possible.

Shortly afterwards messengers were seen running all over the Barrow Dock side. One rather breathless person greeted the lieutenant in charge of the boats: "Will you cum and zee yon torpido; he is stuck in yon wall with his screws awhurring and awhurring." The messenger was right, and there was the 18-in. sticking half-way in the top part of the shelter that "No. 5" submarine was lying in, with the propellers rotating at 2000 revolutions per minute and the many lookers-on afraid to touch it.

The foreman, being bent on putting the leaky valve right in quick time, forgot there was a torpedo in the tube, and, in trying the valve, fired the Whitehead straight into the wooden berthing, 8 ft. from the bow of the submarine. The poor man was rather alarmed at the result, and when informed that the Admiralty would make him pay for a new torpedo, had visions of a few snug little cottages on the shores of Windermere Lake coming under the hammer to satisfy the claims of "My Lords"; fortunately for him, the wood was rotten, and the 18-in. was little the worse for being placed in such an unusual predicament.

The method of discharging torpedoes is similar in most submarine boats that use an expulsion tube for the purpose.

In later boats the operations are simplified to some extent to what they were in the Holland design. In a large number of French submarines no expulsion tube is fitted, the torpedoes being carried

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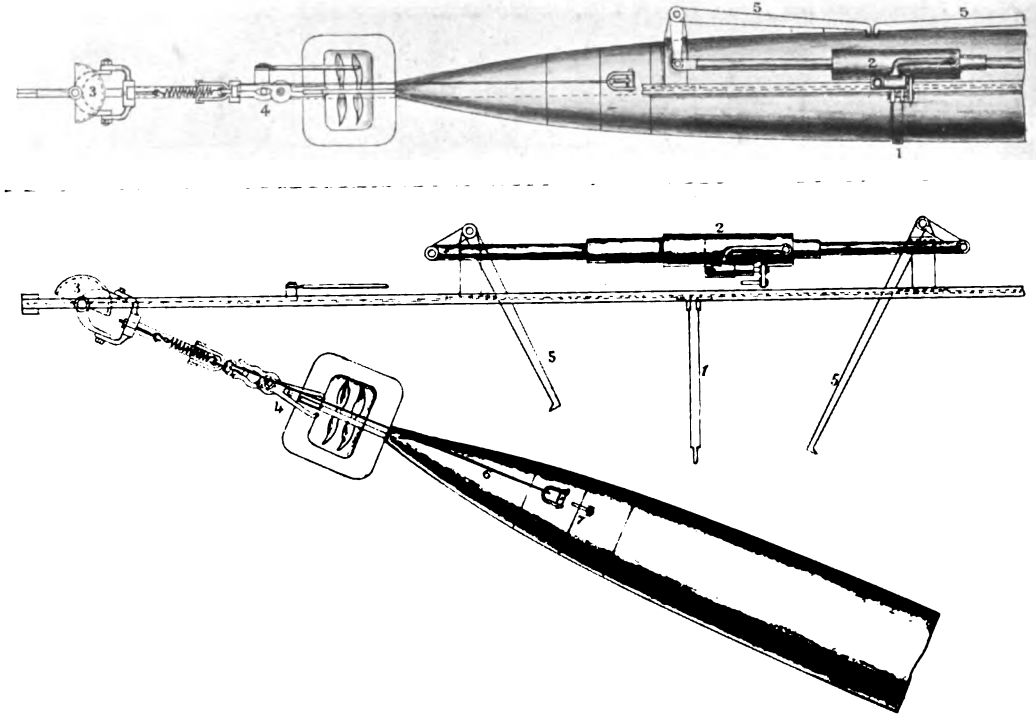

FIG. 88.—*M. DRZEWIECKI'S SYSTEM OF DROP COLLARS.*

1. Flexible Steel Bands.
2. Pneumatic Piston and Firing Bar.
3. Cones.
4. Claws.
5. Push Rods.
6. Lanyard for pulling back Air Lever.
7. Air Lever.

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externally in Drzewiecki drop collars; these can be seen on looking at the "Narval" (Plate 22).

A description of this method, taken from *Les Bateaux Sous-marins*,* is well worth passing notice, as this system is not in use in any American or British boat.

"The torpedo is carried in two flexible sling bands, about 6 ft. apart, these bands being locked to a firing bar, supported by a fore-and-aft bar forming the main frame, as shown in Fig. 88.

"This firing bar has a pneumatic piston which, on letting air into one side, shoots the firing bar forwards and unlocks the steel bands. The boat going through the water and being submerged naturally causes a pressure of water to act on the head and sweeps the torpedo to the angle set on the cones, which are connected to two claws working on the extended scissor principle; these grip the inside of the tail, the adjustable cone is set to any desired angle;† when this is reached a powerful spring actuates the claws and releases the torpedo. At the same time the air lever is thrown back and the compressed air is admitted to the engines of the torpedo, propellers are revolved, and the torpedo moves itself off in the exact direction to which the releasing cone was set.

"The claws are short or long according to the type of torpedo being used and the method employed in gripping the tail; specially strong tails have to be fitted to stand the strain of this means of discharge; and, when fitted in destroyers, recent experiments show that torpedoes can be fired when the boat is travelling at a speed of over 20 knots. The frame being very light, a great saving of weight is obtained in comparison with a tube in this class of ship."

In submarine boats the great disadvantage of this gear is that, being carried externally, it is liable to damage from seaweed, wreckage, etc., and in addition it is difficult to keep in exact working order, as the parts may become strained in a seaway. When the gear is in good working order it appears very neat, and to see a torpedo move itself off when one is looking through a scuttle 10 feet under water possesses great fascination for a torpedo-man; the suspense as to whether it will release at the exact angle it is set for, adds zest to the experience.

A review, however brief, of the locomotive torpedo attacks that

* These details are by permission of M. Drzewiecki.

† Torpedoes can be discharged from 10° of right ahead up to 160° on either side.

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have been carried out in actual war must prove not only of interest, but material aid, to those who may be desirous of obtaining an insight into this branch of naval warfare, for the experience so gained ought alone to be the basis on which to commence the study of the value of the torpedo.

On January 25, 1878, the Russian "Tchesmé" and "Sinope" fired one Whitehead torpedo each at a Turkish revenue cutter at the entrance to the harbour of Batoum, both of which exploded under and sank the Turkish vessel.

On April 23, 1891, the Chilian insurgent battleship "Blanco Encalada" was anchored in Caldera Bay, when she was attacked by two torpedo gunboats belonging to the Government. These gunboats, called the "Lynch" and "Condell," were at Valparaiso, and, having nobody to adjust the torpedoes, they shipped a French artificer who, during the search northwards, managed to overhaul them. The captain of the "Condell" heard the revolted battleship was in Caldera Bay, and arranged that the plan of attack was to enter the bay singly and creep as close to the ship as possible, fire the stern tube, and then the beam tubes. The "Lynch" followed close behind the "Condell," and, on sighting the "Blanco Encalada," went straight at her, firing her bow, and then her beam torpedoes; all three missed, the battleship opened fire with light guns, etc. The "Lynch" came up unobserved, fired her bow tube at 150 yds. off, which missed, then, altering course, fired a beam torpedo, which hit the ironclad amidships, sinking her in 6½ minutes, and drowning 11 officers and 171 men. The damage done to the "Lynch" and "Condell" by gun-fire was trifling. Some time afterwards the battleship was examined by the divers of H.M.S. "Champion," who reported that she was lying on her starboard side with a hole nearly amidships 15 ft. in length and 7 ft. in breadth. This is the first known instance of a battleship being sunk by a locomotive torpedo.

Another civil war in South America led to an attack on the insurgent Brazilian battleship "Aquidaban," anchored in St. Catharina Bay, by four Schichau torpedo vessels on April 5, 1894.

The method arranged was for the torpedo craft to enter the bay in single line abreast and search for the battleship. This idea was not carried out, as the vessels lost touch with each other in the darkness, and one of them, the "Gustavo Sampaio," suddenly came on the battleship off the starboard bow, who greeted her with a sharp

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fire of artillery. The captain went full speed towards his enemy, and brought the bow tube to bear and gave the order to fire, but the officer in charge had previously fired, thinking the order had been given before; therefore this shot was lost. The captain, exceedingly chagrined at such an opportunity being thrown away, swung his ship round the battleship's stern, and, when abreast of her funnel, gave the order to fire the beam tube at a distance of 450 ft., but nothing happened. The second officer, hearing the order, rushed aft and fired the torpedo by hand, which hit the "Aquidaban" forward under the port bow. Immediately the explosion occurred the gun-firing ceased and the ship was moved by the engines into shoal water, and took the ground in 22 ft. of water, her draught being 18 ft. The "Sampaio" was hit by thirty-eight 1-inch Nordenfelt bullets, but, strange to relate, only one man was slightly hurt. The other boats failed to make good use of their torpedoes.

In the war between China and Japan,* we find the Japanese torpedo-boats playing a most important part. These were mostly of the French pattern, with turtle-back decks, and provided with one right ahead fixed torpedo tube and one training tube. The boats were supported by two armed mail-steamers which acted as torpedo depôt ships; these steamers convoyed the boats to within seven miles of Wei-hai-wei harbour. Early in the morning of February 5, 1895, seven torpedo-boats attacked the Chinese fleet anchored close inshore. Eight torpedoes were fired; one hit the "Ting Yuen," exploding under her quarter. She was kept afloat for several hours, but finally was hauled into shallow water and abandoned. Most of the attacking boats were struck with rifle bullets, which did little damage. Two boats were hit by a 3-pr. or 6-pr. projectile, causing the boiler of one to explode, and she had to be abandoned; the second burst in the stokehold of the other boat, but did little damage. When coming out of harbour, one boat ran on shore whilst rounding the eastern end of the protecting boom laid across the harbour, and was lost. In the second attack on Wei-hai-wei, on the morning of February 6th, five torpedo-boats took part, acting in two divisions; one division of three boats skirted the eastern end of the boom, the second division jumped the boom between Channel Island and the eastern shore. The Chinese fleet threw their searchlights on the attacking boats, but

* 1895.

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failed to stop them by gun-fire, which the Japanese state all went over the boats. One of the boats, a Yarrow type, discharged three torpedoes, the others two each, and they succeeded in sinking the "Wei Yuen," "Sai Yuen" and "Chen Yuen."

In these torpedo operations by the Japanese the seed of their future successes was sown. The attacks were carried out in the coldest of weather, many of the gallant men being frozen to death at their posts. We have no hesitation in saying that the heroism displayed by these torpedo-boat officers imbued the Japanese in their recent war with that spirit of emulation which is so valuable an asset for an admiral to possess in his torpedo craft flotillas.

Continuing, then, our subject down to the present time: without entering into the causes of the late war between Russia and Japan, we find in reading the Japanese note, delivered on February 6, 1904, this statement:

"The Imperial Government reserve to themselves the right to take such independent action as they may deem best to consolidate and defend their menaced position as well as to protect their established rights and legitimate interests."

The Russian naval officers on the China station stated that for months previous to this date they had expected a severance of diplomatic relations, as they all thought war was inevitable. Most authorities * concede that once a rupture takes place it is the duty of both sides to prepare for any eventualities, and we find the Russian admiral quite alive to the necessity of taking some precautions, as on the nights of February 6th and 7th the ships lying in the outer anchorage of Port Arthur were patrolled by torpedo-boats and picquet-boats. The fleet consisted of the "Petropavlovsk" (the flagship of Vice-Admiral Starck), the "Poltava," "Sevastopol," "Peresviet," "Retvizan," "Pobieda," and "Cesarevitch," with the cruisers "Novik," "Bayan," "Diana," "Askold" and "Boyarin."

About sunset on February 8th, Admiral Togo sent off five divisions of destroyers, consisting mostly of four boats in each division.

* The conclusion recently formulated by Von der Goltz and generally circulated, apropos of President Kruger's action in the two Boer wars, that "the statesman who, seeing war inevitable and being himself ready to strike, hesitates to seize his opportunity is guilty of a crime against his country," applies in this case admirably.

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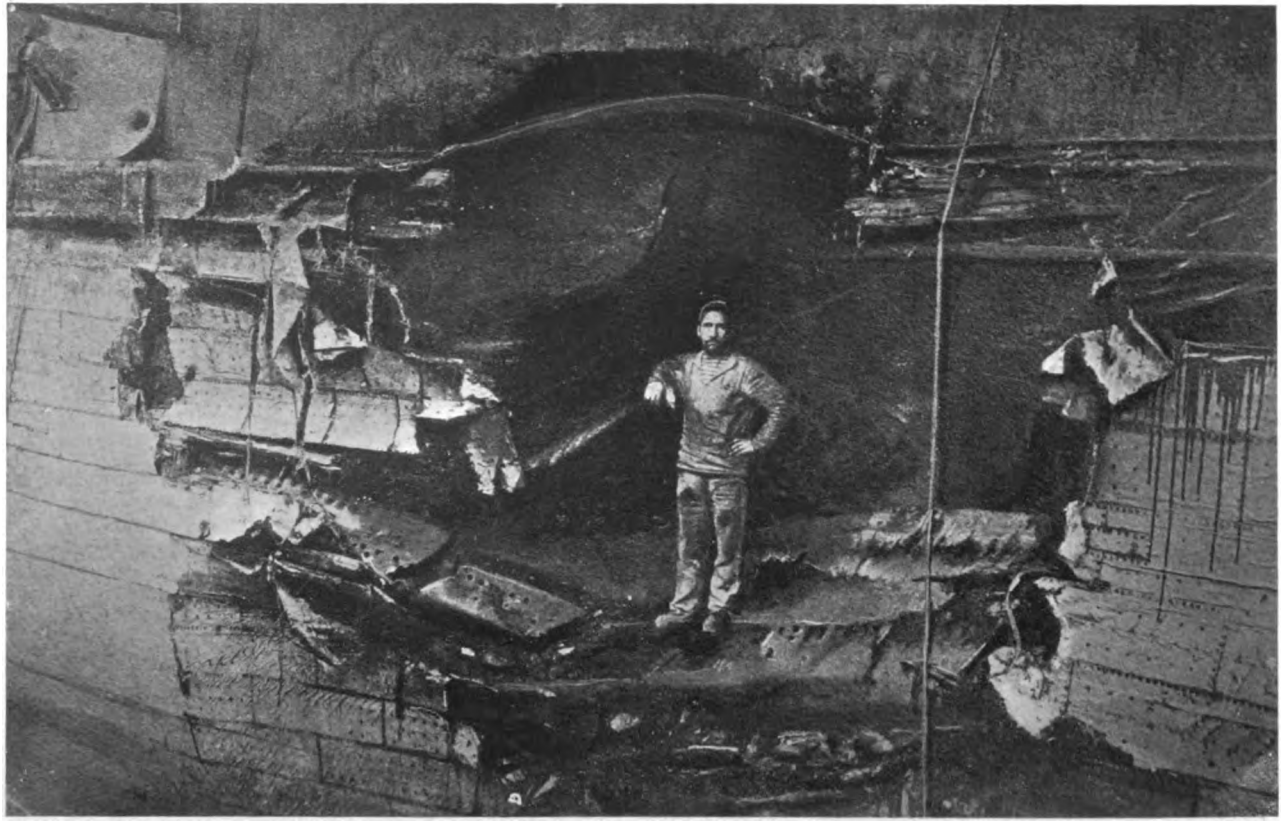

PLATE 102. *INJURY TO RUSSIAN CRUISER "PALLADA" BY A JAPANESE TORPEDO, FEBRUARY 8th, 1904.*

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Three divisions were ordered to attack the ships anchored outside Port Arthur, and the other two were detailed to search for any ships off Port Dalny; these latter divisions were unsuccessful and saw nothing. Off Port Arthur the three divisions got split up, due to a patrolling division of Russian destroyers coming in sight; this caused half the destroyers to bear away to avoid being seen.

The leading division, with a boat or two of the second and third division, avoided the smaller Russian ships and went straight at the battleships; a few minutes after the first dull explosion was heard, searchlights were turned on, and fire opened on the attacking boats, the remaining boats went in to attack also, and after firing their torpedoes they all beat a hasty retreat under cover of the Japanese cruisers in the offing, the forts and fleet keeping up all the time a heavy fire on the fast fading outlines. But it was too late, they had done their work. Admiral Togo's farewell signal wishing the boats success had been brilliantly attained off the very port that diplomatic intrigue prevented the "young power" from holding in 1895. The morning came, and showed the battleships "Cesarevitch" and "Retvizan" with the cruiser "Pallada" all *hors de combat* and unfit to take their place in the fighting line. The damage done to the "Pallada" is shown on Plate 102. The torpedo struck in centre of a coal bunker.

The news of this attack was soon wired to all parts of the globe, and showed in a most effective manner the tremendous potentialities of the torpedo. We can imagine the feelings of the sceptics in modern fleets when they realised the damage inflicted by the often scoffed-at Whitehead. This sudden blow resulted in the complete demoralisation of the Russian fleet in Eastern waters in under half an hour. In pressing the attack home the Japanese skilfully eluded the patrolling boats, and practically were untouched. In another attack a few days later the Russian third-class cruiser "Boyarin" was also hit by a torpedo whilst lying at the entrance to Port Arthur, February 14, 1904.

Nothwithstanding these crushing disasters, the Russians made most strenuous efforts to repair their damaged ships. Plates were bolted on from the outside and stayed up inside with angle-bars, etc. The injury to the "Retvizan" in the first torpedo attack was in the engine-room. A wooden cofferdam plate was built up outside and rough repairs made. The main shaft dropped slightly in align-

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ment, and a considerable amount of auxiliary machinery was damaged.

The "Cesarevitch" was struck on the port side, near the stern, by a torpedo, and a complete new rudder and stern port had to be built for her. It is rumoured that this was sent out by the French firm which built the vessel. The accuracy of this cannot, however, be vouched for.

As soon as the ships being repaired were ready, the fleet once more sallied out of Port Arthur, and it appeared as if the Russians were bent on trying conclusions with Admiral Togo. Not so, however. On seeing a Japanese squadron on the horizon, the signal was made to return to Port Arthur. The fleet retired, being closely pressed by the torpedo craft, which, on this occasion, claimed to have torpedoed a battleship of the "Peresviet" type, and to have also damaged the "Diana" and "Askold." These were, if hit, subsequently repaired. The reason why more damage was not done by the torpedo was that the ships were fully alive to the attacks, and managed to successfully prevent the boats getting at a close range.

On April 25th the Vladivostock squadron, consisting of the armoured cruisers "Rossia," flying the flag of Rear-Admiral Shtakelberg, the "Gromoboi," "Rurik," and "Bogatyr" and several destroyers, started raiding defenceless merchant ships off the coast of Yezo—a few small merchantmen were torpedoed by the destroyers at Gensan.

Also* it will be remembered how, on June 12th, the Russian cruisers "Rossia," "Gromoboi" and "Rurik" unexpectedly emerged from the harbour at Vladivostock. On the third day out they fell in with the steamers "Sado Maru" and "Hitachi Maru," both of 6000 tons, in the Tsushima Straits, transporting soldiers and military stores from Shimonoseki to the mainland. The "Hitachi Maru," commanded by Captain Campbell, refused to stop, and was sunk by the guns of the "Gromoboi"; but the other vessel, disabled by gunfire, hove to, and such of the non-combatants as desired were allowed to leave in boats. She was then torpedoed on both sides by the "Rossia," and the squadron hurried northward again, leaving her apparently sinking. She remained afloat, however, and was towed

* *Engineering*, Oct. 7, 1904.

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PLATE 103.—*INJURY TO S.S. SADO-MARU BY THE FIRST RUSSIAN TORPEDO—STARBOARD SIDE.*

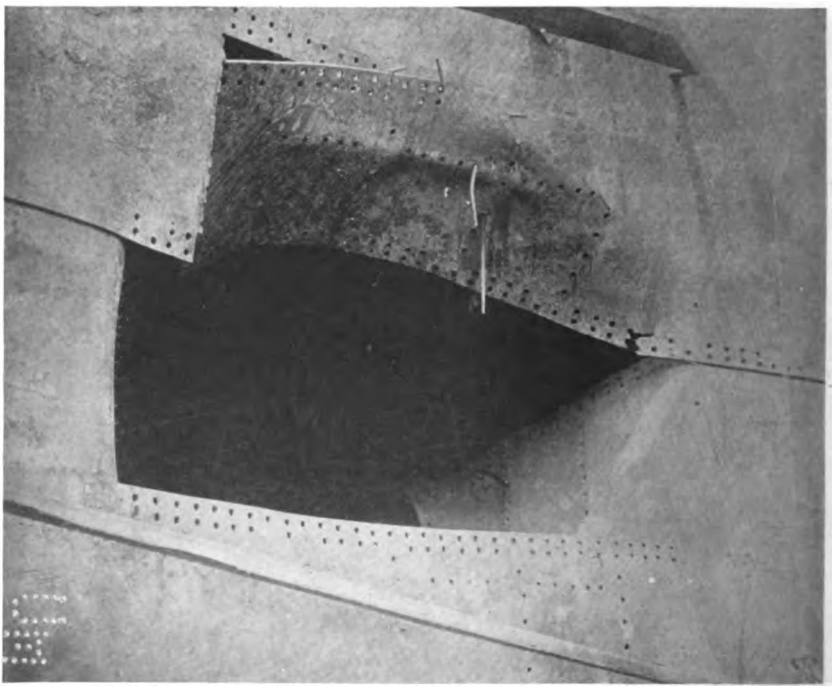

PLATE 104.—*INJURY TO S.S. SADO-MARU BY THE SECOND RUSSIAN TORPEDO—PORT SIDE.*

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into Moji, and beached in shoal water. From the appearance of the vessel one would hardly suppose her to have suffered very serious injuries, whereas below the water-line such huge holes had been torn in her sides that it is almost incredible how she could remain afloat at all. The first torpedo struck the vessel on the starboard side opposite the engine-room, leaving a hole, as shown by Plate 103, 16 ft. by 17 ft. in the outside shell, through which, in the original photograph, the machinery in the engine-room is visible. The main condenser, the high-pressure front column, the sole-plate, the air, feed, and bilge pumps of the main starboard engines, were smashed, the starboard pocket-bunker entirely blown up, and the ballast-pump, donkey-pump, and spare crank-shaft carried away to the other side of the ship. The screen bulkhead between the engines and boilers was also partly destroyed, and the starboard double-ended boiler was bodily shifted a few inches forward. Plate 104 shows the effect of the second torpedo on the port side. It exploded in the cross-bunker forward of the boiler space on that side, leaving a hole 7 ft. by 13 ft. in the outside shell, smashed the bunker bulkheads, and carried the port double-ended boiler some inches aft.

The Japanese are credited with some success by means of torpedoes fired from dropping gear boats, as two destroyers of the "Bourakoff" class are believed to have been torpedoed. Also it was reported that more than one attempt was made by Japanese officers swimming off the entrance to Port Arthur with a torpedo; but the water was too cold, and caused such severe numbness that these ventures failed. It is generally recognised that the dash of the officers in command of the Japanese flotillas left nothing to be desired, and in the manœuvres before hostilities commenced it is now no secret to say that every destroyer took part. There were practically no breakdowns and few collisions, which speaks well for the personnel employed in these fast craft. The reasons why the torpedoists did not make more of their great opportunities during the first part of the war may be summed up in one sentence: "The captains of the torpedo-boats and destroyers had distinct orders not to run full war risks because, Japan had no reserve of these craft to fall back upon." Neglect of a few minor technical details undoubtedly led to several lost shots with the torpedoes, the most important being:

1. Insufficient supervision of adjustments, as counters, reducers, firing at too great a range, etc.

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2. At night the flash of the powder impulse used in the above-water tubes gave a warning to the Russian ships, and they promptly put their helms over.

3. Water leaked through the net-cutter gland, and drowned the explosive in the war-head.

4. In some cases the torpedoes froze in the tubes.

5. Want of appreciation of the gyroscope.

A large number of the Japanese torpedoes were unprovided with the gyroscope apparatus when war broke out; all later orders were, however, provided with this instrument.

Some of the Japanese torpedoes were found in the Russian net defences, and we constantly read that they had the safety pins still in. This is denied by the Japanese; and it is now generally believed that the shearing-pins of the scissors in the net cutters were mistaken for safety pins.

Admiral Sir Cyprian Bridge, writing in the *Naval Annual* of 1905, on the first stage of the war, remarks: "Perhaps nothing stands out more clearly in the campaign than the insignificance of the results effected by the locomotive torpedo."

On analysing this article, we are at once struck by the many contradictions contained therein, and notice a vein of antagonism towards the torpedo. This continual warfare between conservatives of the old school and progressive specialists has restricted largely the development of torpedo warfare in most navies.

In considering the teachings of this war from a torpedoist's point of view, it must always be borne in mind that the political situation at Tokio was analogous to that existing during the Spanish-American war, when nearly all Europe was against the Americans, who at any time might have had to contend against other fleets. This rendered the strategic problems before the United States War Bureau exceedingly difficult, and, according to Captain Mahan, it was found necessary to impress on all officers the need of caution. The navy was so small that every unit was of importance. "The matter is left to your discretion," the famous telegram ran, "except that the United States armoured vessels must not be risked."

This was the keynote to the whole of Admiral Togo's tactics during the early portions of the war, and not until the Russian fleet from Europe had entered the Sea of Japan did the admiral allow his torpedo flotillas to take full war risks.

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In the fleet action on August 10, 1904, according to despatches from Admiral Togo, sharp fighting commenced at 1 p.m. and continued until sunset. The Russian squadron was broken up; some of the ships, though badly handled, returned to Port Arthur, whilst others escaped to neutral ports. The Japanese flotillas undoubtedly lost a wonderful chance; whether this was the result of some confusion in orders, due to the difficulty of passing signals after the battle, or the necessity of risking as little as possible, is not quite known.

Russian sources, however, state that during this night the Japanese flagship "Mikasa" was mistaken for a Russian battleship and torpedoed. It may be assumed that some combination of unforeseen incidents occurred which prevented further damage with the Whitehead.

When all hope was abandoned of ever forcing the Russian ships through the Japanese blockading lines towards Vladivostock, the small Q.F. guns of the ships, together with their crews, were sent to assist the shore defences of Port Arthur. On the capture of 203 Metre Hill by the Japanese the Russian battleship "Sevastopol" was exposed to shell fire, whereupon the captain shifted his anchorage to under Liaoshau Mountain. Such a tempting target was not allowed to go for long before furious attacks were made by the Japanese torpedo-boats.*

The torpedo nets had been doubled and many torpedoes exploded in the nets without harming the battleship. However, in the last attack, during a snowstorm, a small torpedo-boat succeeded in getting a torpedo into the stern of the "Sevastopol." The explosion carried away a large portion of her rudder, stern-post, etc., also flooded the after-compartments. The next day Captain von Essen, seeing further fighting useless, sank his ship in deep water by opening the kingston valves.

We can imagine the feelings of the gallant captain when he thus ingloriously ended the career of a ship that had borne such a large share of the brunt of battle, having been severely handled by gun-fire, damaged by striking mines twice, and then, after beating off repeated torpedo attacks, was permanently disabled by a torpedo.

It may here be remarked that the gun and torpedo are complementary weapons. Admiral Togo realised this; and all arrangements were made if the Russians should enter the Tsushima Straits by

* Between December 12 and 15, 1904.

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day or night. As they entered by day, the gun was used to great advantage as long as daylight lasted; then came the turn of the torpedo craft, which finished off what the gun had started. If the Straits had been rushed at night the torpedo craft would have started the battle, and the guns would then have finished the work started by the torpedo.

It must be generally admitted that the decisive blow of Admiral Togo's strategy in the last great naval battle of the war was the enveloping of the Russian ships by torpedo craft. These flotillas were smarting under a sense of not having done quite so well as their experience in this method of warfare led them to expect; and on this great occasion we may be sure, had not one single gun been fired from Togo's fleet, his torpedo flotillas would have defended the Straits of Tsushima with their last breath, and we do not doubt that the issue would have been almost as crushing as the combination of these two weapons made it. From a close scrutiny of many press reports on the great naval battle in the Sea of Japan during the night and morning of May 27 and 28, 1905, torpedoists may, I think, fairly claim that the battleships:

"Kniaz Souvaroff" (13,516 tons), attacked on two separate occasions by destroyers, was hit by at least three torpedoes and sank on night of 27th;

"Sissoi Veliky" (8889 tons), torpedoed during night of 27th, and sank morning of 28th;

"Navarin" (9476 tons), hit by torpedoes on both port and starboard side during night of 27th, and sank almost immediately.*

And armoured cruisers:

"Admiral Nakhimoff" (8500 tons), torpedoed on night of 27th and sank during forenoon of 28th;

"Vladimir Monomakh" (5754 tons), torpedoed on night of 27th, and sank during forenoon of 28th;

"Dmitri Donskoi" (5893 tons), torpedoed on night of 27th and sank on morning of 28th—

received their *coup de grâce* from the locomotive torpedo at the expense of three Japanese torpedo-boats, which were sunk by gun-fire. It is interesting to record that more than one Japanese torpedo-boat actually signalled that submarine boats were in sight—a mistake that

* This battleship is supposed to have been struck by four torpedoes almost simultaneously.

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arose through the rounded bottoms of some of the Russian battleships that had turned turtle suddenly appearing and being taken for the oval back of a submarine.

The torpedo, when used from a surface vessel, has the disadvantage that the crew, being exposed to gun-fire, do not make the most of their weapon, and are apt to get over-excited. This leads us to advocate that under-water vessels are the best means of taking a torpedo within striking range of an enemy's ship. All adjustments are made, tubes loaded, long before the submarine reaches her objective; and, not being under gun-fire, no undue excitement should occur in getting a bearing on and, when within range, in pressing the key for firing the torpedo.

The conditions in warfare are practically the same as when taking a shot at a cruiser or battleship during peace manœuvres. This point cannot be too strongly borne in mind when estimating the potential value of the submarine boat.

In summing up, we may say that the influence of the locomotive torpedo has been far more extensive than is usually supposed. Its introduction into battleships has made fleet operations possible only outside its range. Once this began to be generally recognised, long-range gun-firing quickly followed. In design of battleships and large cruisers finality has by no means been reached in attempts to miminise the damage that may be done beneath the water-line by the explosion of a torpedo. European navies do not publish the results of their torpedo practice. The best report I have been able to find is that of the U.S.S. "Missouri," which fired twelve shots from her submerged tubes, at a target being towed at the rate of 10 knots, when steaming at a similar speed in the opposite direction 1000 yds. distant, and secured ten hits; those that missed were within a few feet of the moving target. In America more attention is paid to the efficiency of the locomotive torpedo than in almost any other country. Prizes are often awarded to the torpedo-tubes crew for the best series of runs in test competitions; and it is recognised that, by developing a spirit of emulation in the torpedo branch, the torpedo-tube will assume its rightful position as being more deadly than the gun.

In fast craft of small displacement the influence of the Whitehead has been most marked, and it is only necessary to glance at the different types of torpedo craft produced in our country to take this formidable weapon into action. In 1877 Messrs. Thornycroft built a

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fast torpedo-boat, and two or three years later armed her with a torpedo tube for expelling the Whitehead torpedo. From that time fast torpedo-boats were constructed which gradually improved in fighting value, *i.e.* speed, armament, endurance, habitability, etc.

Many of these torpedo-boats were added to the British Navy List. Other countries were not backward in recognising the enormous value of the Whitehead torpedo when carried in small vessels of great speed. France built a large number of small torpedo-boats for coast protection and for swarming all narrow waters in the vicinity of her coast-lines. This menace was kept constantly in view on our side of the Channel, and the Admiralty replied with the "Scout" and "Fearless," of 1580 tons displacement, having an armament of seven torpedo tubes, four 5-in B.L. guns, and eight 3-prs. These vessels were primarily meant to act as torpedo craft, and in addition were supposed to be capable of running down hostile torpedo-boats.

This type had no great steaming power, and was recognised as being too large a target for operations against hostile torpedo-boats; consequently a new design was brought out, and known by the name of "Rattlesnake," with a displacement of 550 tons.

This ship and the subsequent improvements on her were generally regarded as failures, inasmuch as they had exceedingly poor steaming capabilities, rolled unduly in moderate weather, and were quite unable to overhaul torpedo-boats, even when the latter were handicapped by the most arbitrary peace-manœuvre conditions. Many efforts were made and much money expended to give these so-called torpedo-boat catchers speed, but all attempts failed; so a new departure was made in what is now known as the torpedo-boat destroyer, and first represented in our navy by the "Havock," of 240 tons displacement, launched in 1893.

These fast vessels have gradually tended towards increase of displacement until, as the table shows (p. 327), the "Swift" class has been reached. In addition to the destroyers, several "Scouts" were built, which are now used for working in conjunction with the destroyer flotillas, and it is believed they have been found more useful in this rôle than when working entirely with the fleet.

It is well known that over twenty destroyers were available at Port Arthur prior to commencement of hostilities, and yet only one

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SURFACE TORPEDO CRAFT.

Name and Type.	Date of Launch.	Length.	Beam.	Displacement.	I.H.P.	Speed.	Torpedo Tubes.	Armament.
		Ft.	Ft.	Tons.		Knots		
Torpedo-boats.								
Lightning (No. 1) .	1877	84½	10⅝	27	460	18	1	..
No. 45	1886	125	12½	60	700	21	4	2 3-prs.
No. 92	1894	140	15½	130	2,400	24	3	3 3-prs.
No. 118 . . .	1902	146	17½	200	2,960	25	3	3 3-prs.
Torpedo-boat Catchers.								
Rattlesnake . .	1885	200	23	550	2,700	18·5	4	1 4-in., 6 3-prs.
Speedy	1892	230	27	810	4,700	20	3	2 4·7-in., 4 3-prs.
Harrier	1893	250	30½	1,070	3,600	19	3	2 4·7-in., 4 6-prs.
Torpedo-boat Destroyers.								
Havock . . .	1893	180	18½	240	3,500	26·7	3	1 12-pr., 3 6-prs.
Fame	{1895 etc.}	210	21	350	6,000	30	2	1 12-pr., 5 6-prs.
Cobra	1900	223½	20½	385	..	34·9	2	1 12-pr., 5 6-prs.
Express . . .	1897	227½	22	465	9,250	33	2	1 12-pr., 5 6-prs.
Velox	1902	210	23	400	..	27	2	1 12-pr., 5 6-prs.
River class . . .	1903	225	23½	550	7,000	25·5	2	1 12-pr., 5 6-prs.
Special Torpedo Vessels.								
Fearless and Scout	1885	220	34	1,580	3,200	15·7	7	4 5-in., 8 3-prs.
"Scout" class—								
Adventure . .	1904	374	38½	2,670	15,920	25·4	2	10 12-prs., 8 3-prs.
Modern Destroyers.								
Ocean-going class .	Bldg.	270	26	790	14,500	33	2	3 12-prs.
Swift	Bldg.	345	31⅛	1,800	30,000	36	?	4 4-in.
Modern Torpedo-boats or Coastal Destroyers . .	1905	170	18	225	3,750	25	3	2 12-prs.

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Japanese ship is supposed to have been struck with the Whitehead torpedo. There is only one conclusion to be drawn, and that is, that the crews were imperfectly trained in their weapons.

The Russian naval officers in command of these torpedo destroyers appear to have suffered from a misapprehension as to the proper functions of their vessels, as, with one exception,* they never used them in attacking the main Japanese fleet, or even attempting to bring off any operations in this direction; all they did was to confine their attention to keeping Japanese torpedo-boats and destroyers off.

In connection with this subject, emphasis must be laid on the unsuitability of the name destroyer. What is she to destroy? Hostile torpedo-boats? But when these are as large and fast as herself, some difficulty may be experienced. For instance, how is a river-class destroyer, of 550 tons displacement and 25 knots speed, to destroy a German Schichau torpedo-boat of 530 tons displacement and speed of 30 knots?

The name appears to be a misnomer. Torpedo-boat destroyers, as usually built, are merely fast torpedo-boats. The new ocean destroyers, of 750 tons displacement, with a speed of 33 knots, may have some pretension to the name destroyer, but the majority of our so-called destroyers should have their name altered to sea-going torpedo-boat, their main armament being the torpedo. That the Admiralty have partly recognised this play with names may be noticed in the recent decision to give the so-called coastal destroyers numbers instead of names, and consider them as torpedo-boats. It is earnestly to be hoped that in the near future this decision will be extended to every boat of smaller displacement than the ocean-going type.

By giving all the old destroyers, including the river-class, numbers, and calling them—what they are—first-class torpedo-boats, the crews would be led to believe that the main armament of these vessels is the Whitehead torpedo. To take their weapon within striking distance of a hostile ship is their *raison d'être*; everything else must be subordinated in attempting to obtain maximum efficiency for this great endeavour. Side-gunnery actions between torpedo

* A Russian destroyer is believed to have hit the Japanese cruiser "Takasago" (4160 tons) with a locomotive torpedo, but no details of this attack are obtainable.

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craft of more or less equal tonnage should be discouraged as much as possible. No doubt these operations can be carried out with great personal bravery, dash, etc., on both sides, as was frequently shown in the Russo-Japanese war, but such actions scarcely affect the general result of the war, whereas a successful torpedo attack on the enemy's fleet may be of vital importance, and therefore every unit that can be brought within torpedo range the better. Operations against the enemy's large divisional torpedo-boats of the ocean-going type should be left to vessels of the "Swift" or "Scout" class, and the sooner we have a number of these new vessels the more efficient will our offensive flotillas become.

The recent decision of the Admiralty to constitute a destroyer base at Dover has passed almost uncommented upon in the press. But the enormous importance of having a torpedo-craft headquarters so close to the Straits of Dover cannot easily be lost sight of, particularly when we remember that Germany is turning the port of Emden, at the mouth of the river Ems, into a first-class torpedo base. This harbour is some fifty miles nearer to our new home fleet's headquarters at Sheerness than Wilhelmshaven, which has hitherto been the most westerly of Germany's naval ports. Under the redistribution scheme, the staff of the admiral in command of all the torpedo-boat destroyers, torpedo-boats, and submarines in our home waters is to be largely increased. The scout "Attentive" has been selected to fly the pennant of the new commodore, who will be responsible for the actual sea-training of the flotillas.

This arrangement will have a far-reaching influence for efficiency in this branch of the service, and we may now confidently expect the formulation of a continuous policy, in regard to structural, strategical, tactical, and personnel requirements, based on actual experience gained by one of the new staff in many years' close association with our earliest torpedo-boats.

The necessity of an adequate torpedo defence of our south coast was most markedly brought home to the British public in the recent* grand manœuvres, when Admiral Sir William May succeeded, after drawing away from Admiral Sir Knyvet Wilson's superior force in the Atlantic, in entering the Channel, and then claimed to have obtained temporary command of it.

Had our destroyers, torpedo-boats, and submarines been organised

* 1906.

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on a proper war footing, the momentary success of such a hostile squadron would, it is sincerely hoped, have been short-lived.

An organisation of our destroyers, torpedo-boats, and submarines is required to provide—

1. An efficient torpedo defence of the narrow waters adjacent to our coasts.

2. Offensive flotillas for more distant action.

3. A reliable system whereby combined movements with the main sea-going fleets and all classes of torpedo craft can be carried out.

That efficiency on these general lines will be evolved there is no reason to doubt. The Admiralty have now provided the bases, materials, etc., and it only remains to mould the whole on sound up-to-date torpedo lines. Under these new conditions mine-laying from destroyers and torpedo-boats may receive some attention, also operations against hostile submarine boats will be closely studied as being an important function of the present day surface torpedo craft.

In conclusion, the Whitehead torpedo is now responsible for a boom in anti-torpedo-boat guns, as most nations, in their new designs of war-ships, are giving great attention to this question. The small calibre gun is no longer in favour for repelling attacks from torpedo-boats.

In recent Japanese and Russian designs, the 4·7 or 6-in. gun is being adopted as the anti-torpedo-boat gun. From our own experience there is no doubt that the old 4·7 is an excellent weapon. As lately as 1906 the "Vulcan" and "Barham," of the Mediterranean squadron, obtained over seven hits per minute per gun, in the gun-layer's test. Many experts consider that the 6-in. gun will be the anti-torpedo-boat gun of the future; but at present a smaller gun seems to be more in favour, as we notice the "Invincible" is to have 4-in. guns for repelling torpedo attacks. The small gun has the advantage that a greater number can be carried.

By more supervision in training, new departures in systems of gun-fire control, introduction of electrically-controlled higher candle-power searchlights, case or shrapnell shot for the heavier guns, etc., the surface torpedo craft is faced, even under the most favourable conditions, with more and more difficulties in pressing her attack home. As this defence of battleships and armoured cruisers becomes more and more developed, so increased demands will be made for the submarine boat, as she is the only weapon that can evade this new preponderance of anti-torpedo-boat armament, both by day and, to a certain extent, by night.

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CHAPTER XXIII.

PROTECTION OF WARSHIPS AGAINST SUBMARINE EXPLOSIVES.

SOME months before the Russo-Japanese war *, commenced the author wrote a paper for the Royal United Service Institution naval prize essay. This was subsequently printed in their Journal. One of the points touched upon at that time was the protection of battleships and cruisers from the explosive effect of a torpedo. In considering the ultimate teachings of this war, no reason is seen to alter in any way the opinions at that time expressed, and the several occurrences during the whole period of hostilities point more and more forcibly to the desirability of developing some system whereby the under-water portion of warships may be more efficiently protected.

It is not to be expected that ships will be able to avoid injury from mines or locomotive torpedoes, any more than they can avoid being struck by projectiles from the guns; in short we want war-vessels constructed with more protection against these forms of attack.

Means must be taken to minimise the damage which may be caused by the explosion of a gun-cotton charge in contact with a ship's hull some feet below the water-line. The whole question of armour, guns, accuracy, and control of gun-fire, etc., has received, and is receiving, so much attention from hosts of naval writers and would-be experts that there is a real and serious danger in neglecting to study, with the help of systematic experiment, how to minimise the effect of weapons of much more deadly potency than any gun ever constructed. To a country geographically situated as ours is, this question is of the utmost important, for our naval forces may at any time be called upon to dispute the narrow waters adjacent to our coasts.

In nearly all existing battleships over 30 per cent. of their

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* 1904–5.

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displacement is expended in armour protection, but the minimum fraction is devoted to defence against submarine explosives.

The recent naval successes in the Far East forcibly show us that most of the decisive *coups* were brought about by torpedoes of the mine or locomotive variety, as shown in Plate 105.

Past modern warship design has been based on the principle that the battleship was constructed primarily for the gun, with the armour to protect this weapon and the crews for working it. Now if a single torpedo or offensive mine is exploded in the vicinity of most warships' outer-bottom plating, they will be placed *hors de combat* for a considerable period, even if nothing worse happens. What avail then is the longest and heaviest of guns or the thickest of armour protection? If disaster occurs, the extra weight makes the ship sink all the faster. We must first admit that battleships cannot for the present be designed to withstand the explosive effect of ground mines with charges of 1500 to 2000 lbs. of gun-cotton. However, it is unlikely that ships will be called upon to operate where these dangers exist.

The weapons that will chiefly be encountered now and in the near future are:

(*a*) The locomotive torpedo, fitted with a war-head containing some 200 to 300 lbs. of gun-cotton.

(*b*) The offensive buoyant mine, containing from 1 to 500 lbs. of gun-cotton or other high explosive. More than this latter quantity will not usually be used, as the mines get too heavy for transport and cannot conveniently be stowed in the holds of mine-layers or warships.

The problem is to design a torpedo-proof ship. The chief points, in order of importance, that warrant attention appear to be:

1. The power to withstand the result of one or two submarine explosions, in contact with the outer skin, without total loss of fighting efficiency. More money might be put in constructional devices for obtaining a greater degree of protection against submarine explosives than was formerly done.

2. Speed. This depends primarily on the maximum speeds obtained by other ships of the foremost naval Powers. A little in advance of their most recent attainments must be aimed at. The last few knots at high speed means very great additional cost and the sacrifice of gun-power or protection; therefore to sacrifice too much for a slight increase of speed is unsound policy. This does not

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PLATE 105.—*WEAPONS THAT LARGELY HELPED JAPAN TO GAIN NAVAL SUPREMACY IN THE EAST*, 1904-5.

The Spherical Mine on left was picked up in the Sea of Japan, 1904.

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mean to imply that slow-speed ships are advocated, as it must always be remembered by designers that a slow ship handicaps all the remainder of the ships in company with her, in squadron warfare, for practically the whole of her life.

3. Guns. The 12-in. type is now a standard weapon, but in the natural evolution of the gun this will undoubtedly increase in size, penetrative power, etc.

4. Armour. A ship designed on a great speed and heavy gun requirement, in addition to No. 1, can practically choose her own range; therefore armour can be cut down to what will keep out projectiles at this fighting range. In the disposition of armour, the protection to material that affects the buoyancy should be considered before the gun. This is the teaching of the battle of Tsushima, for when it began there was a heavy swell on, and the battleships were rolling heavily; consequently the Russian ships were frequently hit at points under the water-line armour, and at other places that became submerged by rolling. This was responsible for more than one of these ships capsizing.

5. Coal endurance. Admiral Rozhdestvensky showed to the world how coal, stores, repairing outfits, etc., could be carried in merchant-ships' bottoms sufficient for the requirements of a fairly modern fleet.

6. Cost.

Captain Mahan, in a recent magazine article, admirably summed up the whole question thus: "When a certain speed has been attained, a small increment must be purchased at a very great sacrifice. What shall the sacrifice be? Gun-power? Then your vessel, when she has overtaken her otherwise equal enemy, will be inferior in offensive power. Armour? Then she will be more vulnerable. Something of the coal she would carry? But the expenditure of coal in ever-increasing ratio is a vital factor in your cherished speed. If you can give up none of these things, and it is demonstrable that without some sacrifice you cannot get the speed, will you then—and this is what all navies are now doing—increase the size of the ship? Yes, you say, by all means. Well, then, where will you stop? Or, the same question in other words, what will you sacrifice in order to get your greater dimensions? Will you have fewer ships—smaller numbers with larger individual power? You will sacrifice numbers? Then you sacrifice so far that power of combination which is essential in military dispositions, whether

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they relate to the distribution of the fleet in peace, with reference to possible war, or to the exigencies of the campaign, or to the battle-field. But if the final decision be, 'We will have numbers as well,' then the reply is you must sacrifice money; which, starting from the question of speed, brings us face to face with one of the great present problems of national policy among all naval nations—the size of the Budget. For the line of reasoning which applies to the 18,000 or 20,000-ton ship will hold good when you have reached 30,000 and your neighbour 'goes one better' by laying down one of 32,000."

This is very clearly put. But to my mind the first point to consider, after settling the displacement, is what percentage should be given to protection from explosives below the water-line. Obviously if a ship is badly damaged under water she is no longer an effective fighting unit. If this damage can be reduced to a minimum, she may be capable of being repaired in a short time, and then take her place once more in the fighting line.

If the vessel is lost, then another similar fighting unit cannot be constructed under about two years or so. Therefore, at all costs naval architecture must legislate to keep the ship afloat, even if badly damaged.

Fortunately warship design is on the eve of radical changes; modern requirements are forcing the hands of naval contractors apace, and the evolution of the battleship has taken a great step in advance by the advent of the "Dreadnought," of 18,000 tons, now the flagship of the home fleet.* A full discussion of the latest battleship design would be out of place in this book, and therefore only a few remarks are made on the argument for large battleships in lieu of a medium type from a torpedoist's point of view. This, on the whole, favours large ship construction both in attack and defence, because in the former mammoth battleships offer a better target for the locomotive torpedo from surface or under-water torpedo craft; and in defence:—

1. The hull is capable of being split up into a better cellular system to minimise the danger that can be done by submarine explosives, as practically an inner ship can be built many feet from the external skin.

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* 1907.

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2. Greater speed can be obtained by being able to carry more powerful propelling machinery.

3. A large ship can find stowage for a considerable quantity of offensive mines for ocean mining when in touch with the enemy.

4. Magazines can be placed so that they are well clear of the double bottoms, and therefore not so easily detonated by submarine explosives.

The "Dreadnought" and "Invincible" are the latest developments of naval science, and, besides embodying many new gunnery features, we notice considerable attention has been given to protection from explosives acting below the water-line, as provision has been made for:

(*a*) Better cellular subdivision.

(*b*) Solid bulkheads where possible.

(*c*) Internal armour protection below the water-line.

Also, by abolishing the ram, dependence is placed on the Whitehead torpedo from a submerged tube for any close-quarter work.

The few attempts that have previously been made, *re* torpedo protection, are the crude torpedo bulkheads as fitted in the Russian battleship "Cesarevitch," and a similar protection in several French battleships.

Designers in foreign countries have had the idea of armouring the outside hull of a ship below the water-line as a protection, but these proposals have usually been abandoned; and it is known that rigid armour-plates, with many butting joints and armoured bolts, are no very efficient defence against the shattering effects of submarine explosives.

Recently the French naval authorities have carried out experiments by exploding gun-cotton charges against submerged armour plates; the results have not been by any means conclusive. It was thought that American cornpith cellulose, if placed behind a plate, would swell on contact with the water, and thus fill up the hole and stop the inrush of water. It is hardly surprising to learn that in the "Belleisle" experiments the cellulose was sent into the air before it had time to get wet. The idea that coal in a bunker would stop the effect of an explosion is equally unsound, because loose coal would suffer the same fate as the cellulose. A hanging net defence is useful for a ship at anchor, and, if not very effective against modern net-

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cutters, gives the crew a feeling of security which might be useful in increasing the efficiency of night gun-fire and in lessening the strain of long watches. Nets are of little use for ships under way, unless they are prepared to steam at very slow speeds.

It has long been contended that a cushion of water or compressed air is the best agent for minimising the explosive effect. By a greater system of cellular division, and by increased rapid flooding arrangements, with corresponding pumping facilities, it is thought that injuries might be minimised so as not to be too disastrous, as is usually the case from submarine explosives. All compartments would be flooded and subjected to a severer water-pressure test before launching than that now customary; each compartment would be tested like a tank to resist a water pressure varying from 40 lbs. to 50 lbs. on square inch, without undue weeping of rivets.

Private enterprise cannot undertake explosive experiments on a large scale; but to illustrate the points under discussion, three tin cylinders were taken (Plate 106), one filled with water, one with compressed air to 40 lbs. per square inch, and the last with air at atmospheric pressure. These were placed at a depth of 6 feet, and a small charge of gun-cotton detonated under each in turn. The effect was most marked, and shows there is some force in the contention that water or air-pressure might minimise the effect of explosive charges. Compressed air by itself does not offer sufficient resistance, and its expansion is too rapid to take up much of the energy of the blow. A puncture in a bicycle tyre shows how instantaneous the expansion of air is, as the tyre is flat in a fraction of a second. Also a complete water protection is known to be out of the question on account of the great weight involved. But would a hydro-pneumatic protection be difficult to arrange in such vulnerable parts as outside the engine and boiler-rooms, etc.?

What we want is to produce a counteracting force inside the hull that will overcome or minimise the force caused by a submarine explosive in contact with the outer skin. It is not thought that the interior force can be made quite equal to the external force caused by the explosive, but if it could lessen the effect an advance would be made in the protection of the under-water portion of ships from the dangers to be expected in modern naval wars.

On touching a mine or being hit by a locomotive torpedo, the centre of the explosive effect is in contact with the outer skin of the

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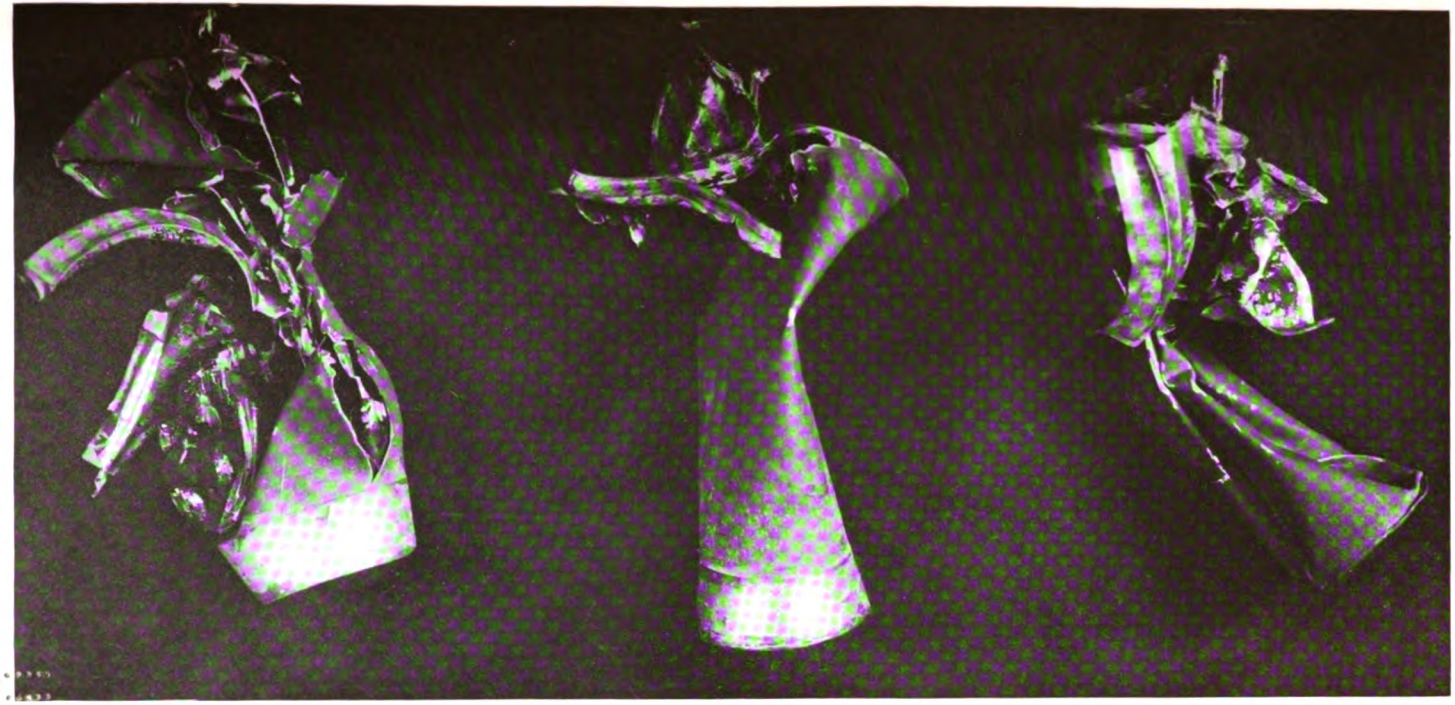

I. II. III.

PLATE 106.—*INJURY TO TIN CYLINDERS BY EXPLOSIVES.*

A quarter of an ounce of Dry Gun Cotton was detonated under each of three tins when placed six feet under water.

Tins Contained { I.—Atmospheric Pressure.
II —Water.
III.—Compressed Air, 40 lbs. to square inch.

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ship. This effect radiates outwards in all directions but soon loses its power.

If the case of an 18-in. locomotive torpedo striking the midship part of a battleship some 10 ft. under water is considered, the force exerted by the explosive would have to be expended in breaking through the outer skin, and it should lose some of its energy in doing this. If a hydro-pneumatic system of protection were used, some of the energy would be taken up by the water protection plus the pressure of air, also the whole pressure of air acting on the water would tend to force the volume through the aperture against the explosive force. This would considerably reduce its energy.

The explosive force would again give up some of its energy in breaking through the inner skin of the double bottom; and finally, the remaining force would be spent against the inner hull. If this were made structurally stiff enough, and provided at intervals with relief hatches placed in water-tight trunks in direct communication with the air, and led above the water-line, so as to take off the unexpended gases caused by the explosion, much damage to the vitals might not occur.

There is no doubt that the destructive effect could be minimised by some such protection, and the additional weight involved in this system would not be prohibitive. If the design allowed for spaces outside the vital parts being filled with water and compressed air when in the vicinity of a coast where danger from submarines or torpedo-boats may be expected, the ship would then suffer the minimum damage by a successful torpedo attack. Ordinarily the compartments would be left empty. The ship would thus have a higher freeboard and a higher gun-platform for fighting in the open sea.

The interior of a ship having such a tank system could be built in the form of a complete internal ship, quite 10 to 15 ft. from the outer skin, so that the inner skin might not be more than slightly pierced by the explosion and the extent of damage come within the capabilities of the ship's artisans to effect repairs of a temporary nature.

The amount of the water-cushion and compressed-air protection round the sides of a ship would have to be arranged so as to allow of a maximum space outside the engines and magazines.

The air-compressors could always be kept going in dangerous

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waters and a sufficient pressure maintained in the tanks to be of great service; this would offer no difficulties, as the ballast-tanks of a submarine frequently retain air-pressure for a considerable time to counteract leaks from a faulty kingston valve or leaky rivet. The rearranging of bulkheads and subdivisions should make a ship almost unsinkable against a torpedo attack, because if any damage is done the inrush of water is so much located.

Whatever material or fluid might be introduced into the spaces, the most important feature is the subdivision into a tank system, with a water and air service, relief hatches, pumping facilities, etc., well developed, and under perfect control. The lessons taught by submarine work show how large volumes of water can be taken in to reduce buoyancy, and if this volume is suitably controlled there is no reason why naval architects should not employ it more readily to compensate for injuries received from mine or torpedo explosions. The compartments and wings of our large battleships and cruisers can now be flooded through a water service controlled by small pipes and kingston valves; these, it is considered, are not large enough for rapid compensating purposes.

If large emergency kingston doors were fitted, so that abundant volumes of water could at once be let into special compartments for compensation purposes, an even keel, under most conditions of injury might be maintained. However large an injury were made, an even keel might be kept if the compensating compartments were immediately flooded.

An allusion may here be made to H.M.S. "Prince George," which was a few years ago damaged by the ram of H.M.S. "Hannibal." A hole on the port side, in the after-submerged torpedo flat, was made, and this compartment rapidly filled. By shifting of weights and admirable seamanship a more serious catastrophe was avoided. If this vessel had been constructed on the tank principle, advocated in this chapter, a few tanks would have been pierced, an emergency kingston door could at once have been thrown open in a compensating tank on the starboard side, abreast of the position of the now existing fore-submerged flat. Scarcely an inclination need have resulted; stability, both transverse and longitudinal, would have been assured, with a minimum loss of fighting efficiency.

The Russian warships damaged at Port Arthur by submarine explosions made use of water compensation to keep their ships on

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an even keel. If the captains of these ships were consulted, I am certain they would advocate a rapid system of flooding compensating tanks with more adequate under-water protection.

It is well known that ready communication must always be provided between engine and boiler rooms, etc., and where doors cannot be eliminated, these must be made as few as possible, and nearly all communication should be from the upper deck, for every door and hole in a water-tight bulkhead is a grave weakness.

We have developed our horizontal internal organisation through water-tight doors so thoroughly that there is no doubt that a more vertical system of ammunition supply and greater personal convenience, as has been arranged for in the "Dreadnought," can be made equally efficient. Huge magazine passages and enormous water-tight doors, capable of allowing ammunition trolleys to pass abreast, are now recognised as being quite unnecessary, and add very much to dangers from injuries below the water-line.

Modern French naval writers are advocating the total abolition of the locomotive torpedo, with its submerged tube, from future battleship designs, as they claim that there is no case in recent naval warfare in which large ships have made use of the torpedo. This is not quite accurate, as there are cases in which the torpedo has been used—though not, I believe, successfully. Might one not argue that the fear of the torpedo from the submerged tube has kept ships in the recent war outside a 6000-yard range?

A great deal too much is made of the space taken up by the torpedo-launching apparatus in modern designs. I quite agree that improvements could easily be made to reduce the size of the compartments now allotted to torpedo work, as again we are taught in submarine boats how a long 18-in. locomotive torpedo can be manipulated through a hatch scarcely bigger than its own diameter; but to dispense with this weapon from large ships would be a retrograde step, as the torpedo must always exert an influence on battle squadron tactics; it has compelled actions to be fought at ranges beyond which it is effective. The modern locomotive torpedo, with a 4000-yd. range and speed of 36 knots, is not a weapon to be despised in a fleet action, particularly now the heavy ram, as in the "Dreadnought" class, has been abolished. Any Togo of the future might suddenly close to short range in a tactical manœuvre to get the better of his adversary. We must not be led into attaching too much

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mportance to very long-range gun shooting; the pendulum has been known to swing in the other direction, and doubtless it will in this case.

It has been suggested that specially built ships may carry submarine boats and, by flooding a compartment, discharge them, as is now done with the Whitehead torpedo, or hoist them at davits. This is quite possible when some other form of motive power is adopted than electricity for working under water. The electric accumulator battery, by being so heavy, puts this outside practical politics for the present, and the experiments in which compressed air or oxygen is used for internal-combustion engines have not yet advanced to any great extent.

In an account of the launch of H.M.S. "Agamemnon" * we are informed that the armour plate of 8 in. as now constructed is more than equal to the armour plate of 12 in. thickness of less than four years ago. As these greater economies of weight are made in armour, and by replacing reciprocating engines with turbines, abolition of water-tight doors, etc., it is confidently anticipated that the saving will largely go in constructional devices for protection of ships from submarine explosives.

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* June 23, 1906.

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CHAPTER XXIV.

TACTICS OF SUBMARINE BOATS.

THE protection of the coast-line of most maritime Powers is entrusted primarily to their navy, and secondly to their fortifications, etc. The original idea of fortifying places of strategic importance was that in the absence of the ships on more important duties, the fortifications could protect the chief naval and commercial ports from attack by sea or land. To obviate the necessity of ships being detailed for this duty and so scattering a large naval force that could be more usefully employed elsewhere, led to a very large expenditure some years ago on fortifications for coast protection.

In the early sixties of last century the British Government appointed a Royal Commission to enquire into the whole question of our national defences, and to deal with proposals for erecting forts at Spithead and other places of importance.

An enormous amount of evidence was taken by the Commissioners from the leading naval and military officers of that day. One suggestion for a protection to the ships at Spithead was to place a boom between the shoals at the Horse Sand and No-man's Land, supported by iron-plated vessels connected by chains. However, bricks and mortar gained the day, and this country was pledged, in spite of strenuous opposition, to one of the most pernicious policies on record, whereby enormous sums of the national money were spent in erecting sea and land defences at various places, avowedly designed for the immediate defence of important harbours, to prevent hostile ships from destroying the dockyards or shipping and to prevent an enemy obtaining a footing on any part of the shore.

Now the methods of attacking any fortified bases for the purpose of forcing a passage to bring hostile ships beyond to action, or for covering the advance of a military force operating on shore have developed the weapon of defence in use.

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Over four hundred years ago some of the chief ports in the South of England were protected by iron chains; the first reference * that can be found dates back to a Portsmouth estimate of February 28, 1522; amongst the items is £40 for making the chains to be drawn over Portsmouth Haven, hire of boats, etc.

Hawkins, in a letter dated December 19, 1585, refers to the "chaine of yron" at Tipnor. Subsequently land and sea forts, assisted by booms, mines, dirigible and automobile torpedoes, etc., have at various dates taken their place in schemes of defence. Quite recently we have developed another defensive weapon, and produced one of man's greatest scientific achievements in the construction of an efficient mobile under-water vessel, armed with the locomotive torpedo.

The defence has usually had three main objectives:—

1. To delay by obstructions the attacking ships, so as to inflict a large amount of damage to their material by gun-fire.

2. To cause as many casualties to the crews of the attacking ships as possible.

3. To damage the hostile ships in their most vulnerable part, *i.e.* the portion below the water-line.

In the former chapters some notice has been taken of the various devices to bring about 1 and 3.

With regard to 2, our present naval artillery has been developed from the cross-bow and hand-gun of the Middle Ages. As the penetration and destructive effect of the missile from the gun increased, so armour-plate protection has developed to lessen the injury to material and personnel. The evolution of the gun and the armour plate would be a most interesting study, and is a gauntlet well worth taking up, should any reader of this book be so inclined. It is doubtful if, in tracing the evolution of the gun and armour plate, the searcher could find anything similar to the antagonistic attitude adopted by most Governments towards inventors who have made strenuous attempts (this does not refer to worthless paper inventors) to bring the ideas germinated by them to a practical issue and so advance the science of torpedo warfare.

The submarine boat has undoubtedly suffered from this hostility in the past, but the recent great advances will soon dispel such ideas,

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* Extract from *Hampshire Telegraph*.

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and these vessels will come to be more generally recognised as necessary adjuncts to the large warships of modern navies.

Whatever future developments may prove, there can be but one opinion at present and for many years to come, that the submarine has become an effective practical weapon, but it has its limitations. We frequently read that the battleship is doomed by the introduction of this new mode of fighting. This is a senseless prediction, a mere repetition of what was said when the first fast torpedo-boat came into being; now we find, far from the battleship becoming extinct, that it is increasing in size beyond all expectations of a few years ago.

Both the submarine and battleship have their distinctive functions to perform; the former can never replace the latter, and can at best only exert a modifying influence on naval strategy.

The teachings of history show that maritime supremacy undoubtedly rests with ocean-keeping ships. As long as submarine boats cannot keep the sea under all possible conditions of weather they are simply weapons of coast defence with limited offensive powers.

The torpedo when first introduced as a formidable weapon changed ideas on warfare, so we must concede to the submarine at least an influence of a similar nature. The torpedo from a submarine introduces a new element in naval warfare, and though it may be a small element, it is bound in time to modify some old doctrines. We are told that naval strategy is unchangeable, but we cannot say it is wholly independent of the engines of war. The elementary principles of strategy do not vary, but have the same validity for all ages. Such laws, however, are few and general. The manner of using our weapons and the weapons themselves change from time to time. The details of war thus depend in some measure on the value of the latest scientific invention. Whenever an important weapon is introduced the question may arise, "Is this distinct from other methods of fighting, or can it be classed in the same category as existing types?"

Even if we start from the hypothesis that the submarine is an effective weapon within limitations, there can be no doubt that modifications will be needed in our methods of coast warfare. A calm view of the question will hardly show that the submarine is an unsound idea, and will be useless in a naval war.

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The submarine has brought in the necessity of a twofold set of tactics. Squadron warfare is still valid for the open sea, but new methods must be devised for offence and defence in narrow waters. Strategists may ask how is this method to modify fundamental ideas of naval fighting? By considering the submarine as a weapon entirely apart from the battleship or armoured cruiser. On attacking such a ship, either by a direct attack with the Whitehead torpedo or dropping mines across a possible course, we find the crew of the large ship provided with the most indifferent form of defence against the sub-aqueous vessel.

Various proposals have been put forward. It has been said that a submarine can be easily destroyed by a battleship with quick-firing guns. In this case it is assumed that a submarine must always come to the surface to take bearings, and must be exposed to gun-fire, if only for a few minutes; but this is unnecessary in the modern type of submarines.

These boats, with conning-tower awash or with only a periscope showing, form a poor target even for modern naval artillery. When the periscope is taken right under the surface no target exists. The large warship has then no protection except perhaps torpedo-nets; these if used would cut down her speed to a very few knots; and this defence, though good under certain conditions, is not entirely impervious to a modern net-cutter placed in the extreme end of the locomotive torpedo. The larger the battleship or cruiser, the greater then is the opportunity of the submarine.

With the warning that battleships and armoured cruisers must keep in the open sea, and that the lines of blockade have receded to the patrolling and masking of distant divisions of the enemy's forces, we notice that no essential modifications of present-day methods are needed. It is when we pass to the question of narrow waters and of coast operations that we may expect the greatest differences. Nations must consider the geographical conditions of their coasts, and of those belonging to any possible combination against them; this, of course, is difficult, because no calculation can foretell naval alliances and movements, but it is clear in what parts warlike operations would be most serious and are most probable.

We may take this as our general principle, that narrow waters, if known to be near submarine stations, are untenable for ordinary warships. If we admit that the submarine is reliable in its own

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sphere, we must recognise that a change is necessary, not only in the disposition of our forces, but also in the ports which we have chosen for our bases.

The radius of one of the smallest type of modern submarines is 400 miles from a coast on the surface, and 25 miles under water. Big ships will no longer be able to come within this latter rough estimate without considerable risk. Hitherto torpedo craft have been able to go within sight of an enemy's port, and to trust to their speed for safety in reconnoitring. But now even these fast vessels will not come within the range of submarines without running a risk; and the risk will be greater for battleships and cruisers. There is no alternative, except that battleships must avoid all narrow, close waters infested by submarines, and must keep well out to sea; if they venture within the range of submarines, they must be so constructed that the explosive effect of a torpedo is minimised. Instead of a close blockade of the enemy's ports, fleets must take more to high-sea operations, and give up largely the old coast fighting. If only the enemy will submit to be met at sea, this policy is nothing new for a superior Power. It has always been held that such a Power must try to annihilate the enemy's ships in a fleet action, and the blockade has come as a second step. The battleship must still be the fighting unit on the ocean, and squadron warfare will be as important as ever.

Recent naval wars show that efficient battle squadrons will not be easily thrown into a *mêlée*, but that the side which has the superior tactical and scientific training will undoubtedly beat a numerical equal. Fleets will still be able to employ that species of blockade which prevents the junction of an enemy's forces, but instead of masking ships in ports they will have to mask squadrons from different nations or from different stations. Wireless telegraphy will be a great factor in these operations and enable an admiral to keep touch with units at very great distances. The entrances to narrow waters must be watched by small fast craft of the scout and ocean-destroyer type, as it will be of no gain for an offensive policy if battle squadrons and large armoured cruisers are kept within range of hostile torpedo craft, surface or submerged. The tactics of Admiral Sampson off Santiago would no longer be possible in the vicinity of a base protected by submarines; the risk of loss to material and personnel would be disproportionate to the advantage,

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and as regards the defence, the fleets can go farther afield, knowing that these ports can be safely left to the care of coastal destroyers, torpedo-boats, and submarines.

Whatever is thought of the submarine, all authorities now agree that it is the weapon most suitable for a mobile defence of our ports, being inexpensive and simple. These boats, assisted by look-out craft with a greater range of vision from bridges and from a higher freeboard, could resist every form of attack, while a boom defence across the mouth of a harbour is sufficient to guard against surprise or against an enemy which might succeed in evading the watching boats. Submarines running on the surface can patrol the neighbourhood just as if they were torpedo-boats ; indeed, it has been recognised that the ordinary torpedo-boat will largely disappear in favour of the submarine boat.

Modern submarines are almost self-contained, and have a fair radius of action, which can be increased by towing behind merchant vessels or parent ships. They then could be dropped off an enemy's port, and would be fresh for work, having their batteries charged, ready for action, full up with gasolene or petroleum, etc. Their mechanism, when once understood, is quite simple, and if kept in an efficient state should give little trouble. With a well-trained crew long distances can be covered awash, on the surface, or totally submerged.

The late Admiral Makaroff, of the Russian Navy, invented a submerged microphone, which is supposed to indicate the whereabouts of torpedo craft on the surface or submarines under water. This is no new idea ; microphones have been used for many years in informing the defence of the approach of attacking surface-boats. Unfortunately, these instruments give no accurate idea of direction, distance or depth, three rather necessary factors. We may say, without much fear of contradiction, that the defending ship would suffer severe nerve tension if the approach of an invisible enemy was known, and that the knowledge hardly contributes to defensive measures. The hydroscope, by which submerged vessels are to be located by sight, needs scarcely any comment. It is extremely difficult to see, in a submarine running submerged, more than a few yards even in clear water, and it is unlikely that the instrument will ever be developed to be of sufficient value to enable a surface vessel to observe a submarine under water.

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The chief defects of present submarines as offensive weapons are:

1. Low speed.
2. Comparatively small radius of action when submerged.
3. Limited range of vision.
4. Enervating effect on crews.

We may assume that these defects are not likely to be remedied entirely, but improvements may be expected. The destroyer is the development of the first torpedo-boat, and similarly, fast submarines will probably emerge from the embryo type.

Admiral Aube advised that submarines should be carried on board ship and dropped at the psychological moment. Experience has, however, shown that this was not very successful in the case of torpedo-boats. The reader will naturally ask what means of protection can be suggested against these craft, either dropped from a battleship, slipped from a towing vessel, or working from a base.

Some few years ago a considerable number of experiments were carried out with the idea of destroying submarines by means of a gun-cotton charge placed on the end of a spar. This is attached to the quarter of a destroyer which chases the enemy as soon as the latter is visible. The spar is swung out, and, when over the submarine, the explosive is detonated. Experiments with the spar torpedo are reported as being quite successful—when the submarine is seen! Americans have placed live animals in a submerged tank and exploded charges at various distances. The animals were quite unhurt. An experiment, previously alluded to, but which is worth emphasising, showed that when the French placed several sheep in the "Naïade" and submerged her, the torpedoes fired at different distances had no effect on the animals; and on officers taking their places the experiments were repeated. The observations then taken showed that unless a charge is exploded when in intimate contact with the hull, little damage will be done to the submarine.

An admiral recently said: "We want howitzers firing shell at an elevated trajectory which will explode at a given depth beneath the water." It is as yet impossible, however, to destroy a submarine by an explosion produced under water from gun-fire. Up to the present we do not possess a single gun which can send a projectile

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any distance under water. When a projectile strikes the water its nose is thrown up on impact. The base of the projectile dips in lower, but scarcely more than a foot or two before ricochet occurs. A lucky shot might carry away the periscope and prevent observations, but could do no damage to the boat's power of manœuvring completely under water. With a view to defending a narrow passage of water, a net 250 ft. long, made of thin steel wire, was attached to three steam picquet boats and stretched across one of the channels leading to Portsmouth harbour. Three submarines were told off to attack them, which they did by endeavouring to dive underneath the net. By means of the attachments to which the nets were affixed they could, however, be lowered to almost any depth, and so this manœuvre was checked. Another advantage for the nets is that, on a submarine approaching, the two outer steamboats can close in, and by thus encircling the submarines prevent their escape. The manœuvres were witnessed by some naval officers, but no one else was allowed anywhere near the scene of operations.

This system of netting submarines undoubtedly possesses great possibilities, and may be highly satisfactory on a calm day, when the boat has been located to be within a space of water containing a few thousand cubic feet or so. To the submarine officer this device may be classed in the same category as the gun-cotton charge carried on the end of a pole, which has been rather aptly alluded to by our friends across the Channel as placing salt on a sparrow's tail! (Plate 107).

In addition to these, the following devices have been suggested for use against submarines:—

1. Explosive charges towed by fast craft.

2. Small torpedoes fired with a time-fuse, adjusted to explode over a submarine if bubbles are seen.

3. Miles of fishing-nets, fitted at various intervals with small gun-cotton charges, battery, circuit-closer, and soluble insulator, for safety to those laying.

4. Spans of grass hawser fitted with cork floats in the middle and weighted at the ends to upset the longitudinal stability of a boat which might run into them.

5. Offensive mines dropped off submarine bases of enemy.

6. Smoke-balls to cloud periscopes, as tried against early French submarines.

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PLATE 107.—"*No. 4*" *SUBMARINE AFTER HAVING BEEN CAUGHT IN A NET. PERISCOPE BADLY DAMAGED.*

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None of these methods are really satisfactory. Practically nothing has been done up to the time * of writing by any nation to counteract the submarine menace; consequently reliance has to be placed on surrounding a ship or ships with small units of the scout and ocean-destroyer class. Good as such craft are, it is doubtful if these types are really adapted for the task of destroying submarines, because (1) each has a large turning circle; (2) they offer a large target both to the surface and sub-surface vessels; (3) are easily put out of action by gun-fire, and the crew are unprotected.

The destruction of submarines must be a waiting game, and they will be caught only on coming to the surface through any of the following causes:—

1. Entanglements by nets or hawsers, or injury from a gun-cotton charge.
2. Exhaustion of electric batteries.
3. Defects to internal mechanism.
4. Defects to external gear of diving rudders, and the like.
5. Bad fumes, producing the collapse, or partial collapse, of the crew.
6. If the periscope is shot away a porpoise-like rise and dive may be necessary to obtain a bearing.

Submarine boats have now begun to take their place in properly organised coast-defence flotillas.† France is establishing stations all round her coast, also at Bizerta, Oran, Saigon and other oversea ports of strategic importance. Some of these ports are in ideal situations for controlling narrow waters.

The plant required for the upkeep of the submarines is small and fairly portable, so that stations can be made almost anywhere. These requirements may be classified thus:

1. Gasolene or petroleum storage.

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* May, 1907.

† The submarine bases for our navy in 1907 have been arranged as follows:—

Base.	Parent Ship.	Depôt.
Portsmouth	Bonaventure	Haslar Creek and a Hulk.
Devonport	Forth	Hulk.
Sheerness	Thames	Hulk.
Dover	Mersey.	

Each sea-going parent ship will have a flotilla of nine submarines attached to her, and it is understood that Harwich will be largely used as the training centre of the Sheerness division.

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2. Small shop for making electrical repairs.
3. Charging station for electric batteries.
4. Charging station for air.
5. Slipway or floating dock for cleaning purposes, overhauling tanks, etc.

Nos. 3 and 4, are not essential. If there is plenty of fuel the boats are self-contained and can charge their own batteries or fill up the air-flasks as necessary.

That submarine stations, placed in well thought-out positions of strategic importance, are an absolute necessity in modern schemes of defence, will, we think, be opposed by few.

The policy of the Blue-water school, so ably expounded some twenty years ago by the late Lieut.-General Sir Andrew Clarke, was that it is far better to allocate moneys to provide efficient units for the fleet than to go to large expenditure on defensive works or personnel to man them. This great soldier-statesman then advocated that the Nordenfelt submarine boat should be developed for the protection of coaling stations and important strategic bases abroad—a doctrine that has secured official recognition in France, but in this country we are not yet enjoying its full practical application.

The speech made by Mr. Balfour in 1905 on Imperial defence raised many erroneous impressions; the greater number of writers appear to have quite misunderstood the ex-Premier's lucid reasoning and final summation. This is not singular, as the whole question requires some considerable technical knowledge, with a competent grasp of existing conditions, etc., without which a true appreciation of the line of reasoning is almost unattainable, and most certainly cannot be conveyed in the course of a speech lasting but a few hours, and occupying a column or two in the *Times*.

The hypothesis of an attempted invasion of these shores rests on the assumption that our fleets would have their attention concentrated in looking after the hostile fleets out of home waters, and be all in readiness to intercept a possible combination of the naval forces of any coalition against us. No naval war can be undertaken with any prospect of success that does not legislate for taking the offensive and attacking an enemy in his own waters. To do this, an adequate coast defence must be provided, and be one of the chief elements in any scheme for our permanent security.

A large fleet of heavy battleships, light-draught battleships, or

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armoured cruisers, scouts, and ocean-destroyers, with well-organised defensive torpedo flotillas, would appear to be the true defence of this country. Any scheme developed on these lines limits the sailors tied to our ports to a minimum.

Our rivals do not agree with Mr. Balfour that a sudden raid on our coasts is impracticable. It is all carefully and scientifically thought out, and therefore we must provide an adequate torpedo-craft defence along the waters that are likely to be disputed. If an invading force attempted to land on these shores no doubt the transports would be protected by their torpedo craft, and possibly some cruisers. Lord Roberts stated before the Committee of Defence that 70,000 men would be about the least number with which this attempt could be made. The Admiralty reckoned that a tonnage of close on 250,000 would be required for such a service, and something between twenty-four and forty-eight hours to get these troop-laden transports under way, as this is an evolution that cannot conveniently be practised on any large scale. The expedition would not be so easy of accomplishment when the vessels came within the range of our defensive torpedo flotillas. Look-out stations on shore, torpedo-boats and other surface craft could assist the watching submarines to locate the transports, and, when once sighted, the under-water boats would endeavour to place themselves in the most favourable position for a torpedo attack.

We have recently had brought to our notice how the personnel of a twentieth century fleet of warships suffered from severe "tension of mind," as M. Lockroy rather aptly characterised the entire North Sea incident. The one mistake made by the "Kamchatka" in taking the "Aldebaran," a Swedish trading steamer, for a torpedo craft, nearly plunged us into a European naval war. The captain of the former ship was certain in his own mind, or had official instructions to be genuinely convinced, that an attempt had been made to sink his ship. Thereupon he signalled to the Russian admiral that he had been attacked by torpedo-boats. Then followed indiscriminate firing on the harmless North Sea fishing-fleet, and even their own ships did not escape unscathed.

The transport, then, of troops will be attempted with very grave risks. If the craft bearing the invading force become aware that submarines are in their vicinity, it is reasonable to suppose the "tension of mind" on board the crowded vessels would become some-

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what more acute than that experienced by the Russian fleet, which suffered so acutely from overwrought nerves.

The stupefying effect of the torpedo on hitting the ship would be the first indication of attack; this would provoke a grave and sudden realisation of danger, which might even cause a panic to ensue.

In connection with transport of troops, the question naturally arises, Is it right for a submarine to sink a transport carrying troops for oversea operations for a nation with whom she may be at war? There is no chance of firing a gun across the bows. The submarine can wait for no courtesies of that humane nature. The speed of the transport may be 20 knots, and that of the submarine when running submerged may be 10 knots. Any delay would mean a lost opportunity. The transport is a public vessel of one of the belligerents, against which it is the right and duty of the naval officer to use force by every means not prohibited by international law.* A torpedo attack from a submarine upon a public vessel of the enemy is not prohibited. It is on the same level with sudden fire from a masked battery or from an ambush, and the sinking of such a ship is justifiable; but a sudden attack upon an enemy's merchantmen, not carrying munitions of war, is on a very different footing. An officer's duty with regard to such ships is to capture them, not to destroy them, unless they resist. Therefore we contend that any nation which torpedoed the ordinary defenceless merchant ship would infringe all the conventions of international law by such a retrograde step to the manners of barbarism.

Being able to obtain complete invisibility is where the sub-surface vessels gain over the torpedo-boats or destroyers. This is not always quite understood, as we find such able writers as Sir Cyprian Bridge stating, in connection with torpedo warfare: "Submarines are nothing but handicapped torpedo-boats." Their great power of invisibility is in this statement quite overlooked.

In considering the tactics of submarine boats, there are two aspects to be studied:

1. The tactics of the surface vessel on sighting a hostile submarine.

2. The tactics of the submarine on sighting a hostile surface vessel.

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* Dr. Lawrence on International Law.

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On a battleship or cruiser sighting a submarine porpoising, or seeing her periscope, the large vessel would most probably do one of three things:

(*a*) Put the helm hard over and turn the stern of the surface ship towards the submarine, and, by going full speed, get outside torpedo range as quickly as possible.

(*b*) Steer straight for the submarine and prevent her from firing a torpedo by having to dive deeply to prevent being over-run.

(*c*) Alter course and work round the submarine, keeping out of her danger angle.

Whatever tactics the surface vessel may employ, the chief aim of the captain of the submarine is to obtain all the endurance he can out of himself and crew in a supreme effort to place his boat within torpedo range of the hostile ship. This is the important factor, and it depends absolutely on her commander, as we assume the gyroscope torpedo will run straight, and the range will be close, because, as a rule, there will be no necessity to take the risks of long shots in making an invisible approach. The ability to take up a position of advantage will be easier as the submarine, in the natural order of things, develops.

When once within range the under-water vessel has most assuredly the advantage over any battleship or cruiser. In some few seconds she can place 30 ft. or so of a liquid medium between herself and the projectile striking the water from any gun of the surface vessel. The damage she may be able to inflict is considerable. Some writers discredit the power of the torpedo because the Russian battleships that were injured a few miles outside Port Arthur were able to get inside the harbour, and could take ground before disaster overtook them. If Admiral Togo's ships had been similarly hit, would they in all cases have found a port for repairs? I think most assuredly not. Again, many of the Japanese torpedoes were of the 14-in. type, with under 100 lbs. of wet gun-cotton in their war-heads.

The chief disadvantages to submarine tactics are:

1. Slow speed.
2. Periscope range of vision poor.
3. Vision from conning-tower when hatch closed limited.

Against these may be put the great advantage of invisibility and protection by complete submersion.

If we take the case of a single submarine attacking a hostile

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battleship or armoured cruiser steaming at a speed of 18 knots, and her submerged speed being 9 knots, the submarine should sight the surface vessel at about 6000 yds., and, after taking a careful bearing, dives and runs on a compass course in the best direction to cut the surface vessel off. By porpoising or using the periscope only, the bearing of the hostile ship can be taken and course corrected as necessary. The submarine must be somewhere within the angle SOP (Fig. 89), otherwise she will be unable to get within torpedo range. This is called "the danger angle." Assume that the surface ship steers along the line OP, then if the submarine, making an unseen approach, has estimated the course with fair accuracy, a torpedo shot should occur off Q. The position when making this shot depends on whether the course and speed of the enemy have been estimated correctly; also, if the surface ship can go at more than twice the speed of the 9-knot submarine, the danger angle is reduced proportionally. Should the submarine be unable to travel under water half the speed of the surface ship, and only be able to go 7 knots to her 18 knots, then the danger angle is reduced from about 35° in Fig. 89 to about 30°. In Fig. 90, if the submarine is without the danger angle, as at S, then she would arrive at S^1 when surface vessel is at X, and then be outside torpedo range. It must be emphasised that the submarine is at her best when operating as a day torpedo-boat. Surface vessels of the destroyer or torpedo-boat type can only attack, with any certainty of success, at night.

Modern submarines have a speed on the surface of 13 to 15 knots, therefore at night they can patrol in a similar manner to the second-class torpedo-boat, and have the advantage of being less visible, and without any chance of being betrayed by sparks coming up the funnel, which so often happens with steam-driven surface boats.

In previous blockade work the hostile ships have had to stand off by night to keep away from torpedo attack, and then close in during the daytime. With the advent of the submarine boat ships will have to keep outside the danger zone night and day. Submarines can always lie to on the surface at night and wait for daylight before making an advance. A merchant ship might, under certain conditions, be very useful in towing a boat and slipping her when within under-water striking range.

In addition to isolated attacks are the attacks in groups of submarines, which would usually consist of three boats. Every

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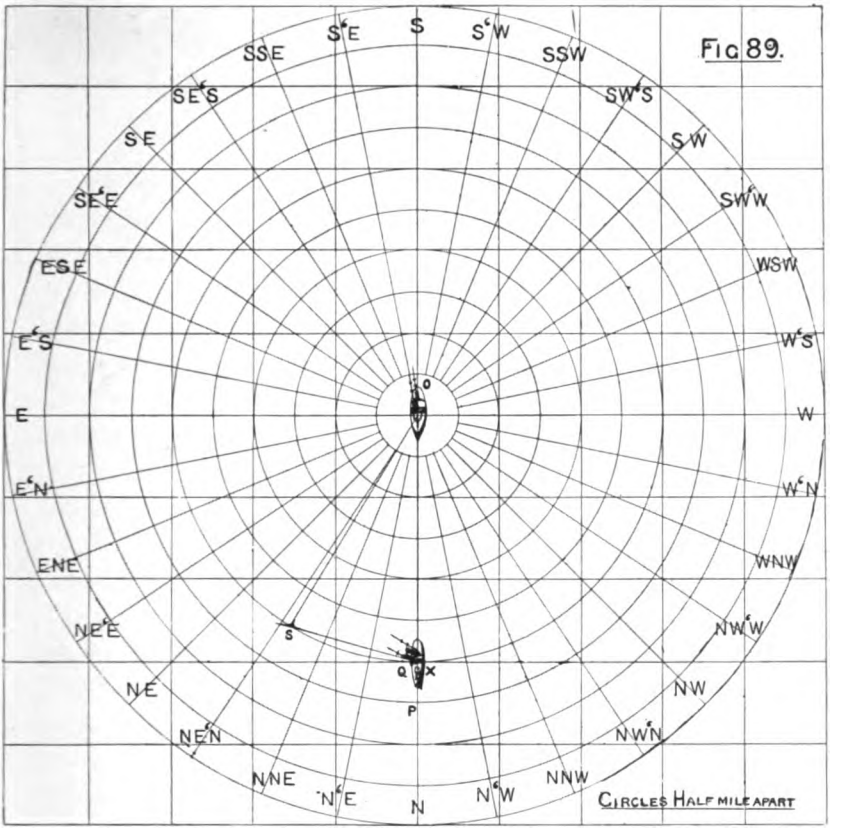

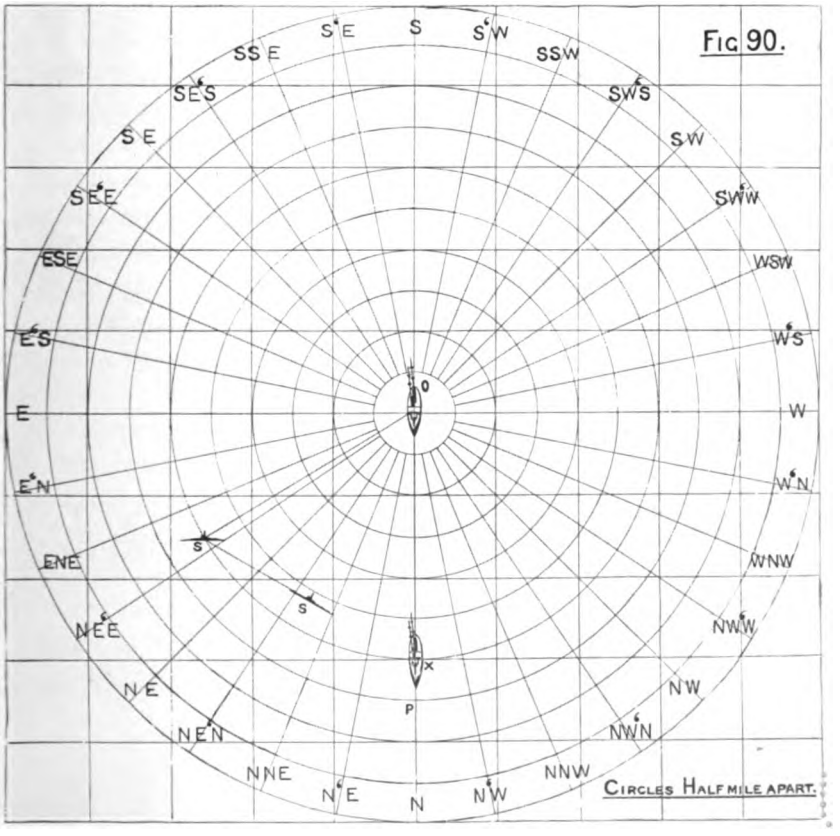

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endeavour would be made by them to get the large ship within the triangle formed by the three watching boats. The boat ahead of the surface vessel, if doubtful of her attack coming off, could always by porpoising show herself in an attempt to make the large ship turn towards one of the other boats and force her into the danger angle of one of them. In cases where a channel might have to be watched by several submarines placed in line abreast, two or three miles apart, the tactics of the boats would be to first take a bearing of the hostile ship; then some of the outer boats, by altering course inwards approximately at right angles to the bearing could, if skilfully worked, be brought within torpedo range of the enemy's ship.

Some interesting speculations are conjured up when one considers a fleet attacked by submarines. What tactics would the admiral employ when he found a skilled leader suddenly floating across his course?

1. Dummy periscopes.

2. Empty shells constructed so as to resemble the conning-tower and upper portion of the hull of a submarine.

Then, perhaps, as his flagship turns away from the imaginary danger, he would find the under-water flotilla amongst his ships.

In submarine attacks on squadrons at anchor, the only protection for the ships are the enclosed harbours with openings protected by booms, net devices, etc. If at sea, and squadrons have to pass through narrow waters in the day-time, known to be infested with submarines, maximum speed must be used, or else dead slow, with nets out and cordons of scouts or ocean-destroyers surrounding them, on the look-out for periscopes, etc. All narrow water passages should, if possible, be passed at night, with everything in total darkness and at maximum speed. In such a case the large ship protects herself from all torpedo craft by invisibility; this is her greatest and only really efficient protection.

The whole question of battleships and cruisers evading submarines is worthy of the closest study. Captive balloons have been proposed to be carried in battleships for locating under-water vessels and mines. These might have an advantage in very fine weather, but the difficulties of marine aeronautation are too great to allow of this being of much practical value. Look-outs on the surface vessels should be placed as high as possible and frequently changed.

No efficacious way of really minimising the submarine danger

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can be suggested but by evasion of the attack. If a passage through these dangers has to be forced, regardless of risks, then speed and invisibility are the two great essentials. Without entering into such a controversial subject as speed, it may be sufficient to state that, in making a rush through a dangerous zone, speed enables a ship to decrease the time in a submarine danger angle to a minimum

We next advocate the submarine boat as the most suitable weapon for Imperial coast defence in the absence of the auxiliary squadrons on more important duties. Under the agreement arranged at the Imperial Colonial Conference of 1887, a contribution to the cost of a small auxiliary squadron in Australian home waters was decided upon; this has been increased from £126,000 to nearly £200,000 per annum, and the Commonwealth has consented to the control over the expenditure of this increment being unreservedly in the hands of the home administrators. Australia contributes certain other moneys to the cost of defence. During the year 1906 she was to expend £800,000 in addition to the subsidy to the auxiliary squadron. This amounted to close on £1,000,000 sterling. As a matter of curiosity, it would be interesting to know on what items the £800,000 was expended. The colony of New Zealand contributes some £40,000 under the same arrangements. The Cape also contributes £50,000, Natal about £35,000, and Newfoundland nearly £3000 per annum.

The late Canadian Minister of Marine had recently been visiting this country with the object of studying the best method of organising a naval reserve. The project was the building of three new cruisers: one for the Atlantic coast, one for the Great Lakes and one for the Pacific. We are only too glad to see any colony making an effort to create its own local defensive navy; this is a natural desire, and it is earnestly hoped the responsible authorities will study up-to-date coast protection.

The whole question of the relationship of our colonies to the mother-country is wanting in a clear understanding. Australia, New Zealand, and Canada are undoubtedly self-contained, but their prosperity, none the less, depends on oversea trade.

Most people interested in the defence of Australia quite recognise that, on the detached squadron being withdrawn by the exigencies of the service under war conditions, the oversea and coasting trade, to the value of some £170,000,000 per annum, is left quite unprotected.

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As the whole prosperity of this colony depends on her trade, it is only natural to find that the rejection, by the Committee of Imperial Defence, of Captain Creswell's scheme of naval defence for their country has been received with a considerable feeling of annoyance in the Commonwealth.

In studying the annual report for 1905 on the naval defence of the Australian Commonwealth, Captain Creswell drew attention to Australia's expenditure in keeping up an armed force; this amounts to 75 per cent. of her defensive outlay for nearly 50,000 men, a number hopelessly inadequate when the enormous extent of Australian coast-line and the comparative scarcity of the population for its efficient defence are considered. The director of the Commonwealth's naval forces, in considering the above, proposed not to use submarines or submersibles in their present experimental stage, but advocated the following policy of construction :—

3 cruiser destroyers.

16 torpedo-boat destroyers.

15 torpedo-boats, first and second class.

To begin with, the oversea trade can to a certain extent run the gauntlet. The opinion of the chief umpire on the grand naval manœuvres of 1906 is that, on the outbreak of war, he considers it probable shipowners would prefer to be left with a free hand as to the action of their vessels as regards routes, time of sailing, etc. One of the most important considerations in connection with this question is, that the Admiralty should afford the latest information in regard to the safety or otherwise of the different routes. If any warships could be spared for protection service, so much the better.

The coastal trade, amounting to several millions per annum, is quite another matter, and for its protection a local defence must be provided. By protection is not meant the patrolling of the whole coast-line, as the ships must run the gauntlet as on the high seas, but there are certain centres, such as the chief commercial ports, that require a mobile naval defence.

The author quite agrees with Captain Creswell that what Australia wants is an efficient torpedo-craft defence of her principal ports, but takes exception to such a preponderance of surface vessels. Are these destroyers to attack a ship in broad daylight that may be lying in the offing, ready to bombard the port unless a ransom is paid, or are they to wait until nightfall and then try and find her?

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Meantime the bombardment has taken place, and the hostile ship made off for other fields. At all costs, raiding cruisers must be thrown back by daytime as well as by night; for the former service a few submarines are advocated, for the latter, small coastal destroyers or first-class torpedo-boats. It may be confidently asserted that if a defence was provided as suggested, raids by cruisers from necessarily long distances would not be worth the risk, were it known that these vessels were on the look-out.

Japan has shown to all nations how necessary it is to provide the very latest weapons of modern warfare; and of all our outlying colonies, Australia is the one that should grasp at an early date modern schemes of coast protection. As we have previously remarked, the defence that will be substituted in lieu of mine-fields will be flotillas of defensive submarine boats; these can be looked upon as outlying mobile torpedo stations, in rear of which searchlights and quick-firing guns of medium calibre will form a secondary defence.

The action of the Commander-in-chief * of the Australian squadron in sending forty Australian and New Zealand bluejackets to Great Britain for training in naval schools, merits the highest approbation, and it is earnestly hoped that a further number will be sent to start the formation of an efficient nucleus for any duty they may be called upon to perform.

During the visit of the colonial Premiers to Portsmouth in May, 1907, the opportunity was taken to show them the latest triumphs of naval architecture, *i.e.* the battleship "Dreadnought" and three classes of submarine boats. The under-water vessels were shown in various conditions of surface trim, and also when completely submerged. These novel-looking craft must have forcibly brought home to the spectators the great advance that has been made in the last few years with this type of war-vessel. In addition to the manœuvres of the submarines, locomotive torpedoes were fired at the "Dreadnought" from the destroyers whilst travelling at high rates of speed, and were caught in her torpedo net protection. After witnessing these torpedo-craft evolutions, it is earnestly to be hoped that our visitors will not lose sight of the valuable lessons that can be learnt from a close study of all the branches of torpedo warfare in its relationship to the protection of their coast-lines and important shipping centres.

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* Vice-Admiral Sir W. Fawkes, K.C.V.O.

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In the last three years our submarines have increased in speed from 7·5 to 14 knots, whilst their tonnage has risen from 120 to over 350 tons, and the motive power on the surface from 160 to 850 H.P. Therefore in their natural evolution they will soon be in a position to completely close all narrow waters to hostile fleets or raiding cruisers.

If the deliberations of the 1907 Imperial Conference result in a scheme for the provision in our colonies of a sound up-to-date torpedo defence, with a system, whereby both officers and men can be kept in touch with the latest developments in torpedo warfare, such as sending them to the torpedo schools in England, a great effort will be made to elucidate a difficult problem, and one that will bind the Colonies closer to us in those moments of difficulty that are certain to arise in connection with the defence of our Empire.

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CHAPTER XXV.

CONTROL OF SUBMARINE AND SURFACE BOATS BY HERTZIAN WAVES.

SOME interesting experiments are now being undertaken by private enterprise in connection with controlling small submarine and surface boats, carrying explosives, by means of Hertzian waves.

A crewless submarine, constructed at the Creusot works has provoked considerable interest in some trials recently carried out in the roadstead of Antibes, Gulf of Genoa. The boat consists of two cylindrical-shaped vessels with cone-shaped ends, displacing about 7 tons; the upper cylinder acts as a float, and is 9 metres in length, with a diameter of 45 centimetres. On this are fitted two masts for supporting the receiving aerial wire at a height of some 3 metres; also on each mast an electric lamp is fitted for indicating the direction of the vessel at night.

The lower cylinder is 11 metres in length and 1 metre in diameter and carries the accumulator battery for furnishing electrical energy to the motors for propelling and steering the boat, also a launching frame for discharging a Whitehead torpedo. The receiving apparatus is placed in the superstructure of the boat; on oscillation being set up in the aerial, the receiving apparatus, on the Branley coherer system, brings into action the motors for steering the boat.

The essential features (Fig. 91) of the system * are :—

"(1) A distributer which moves over a series of contacts connected to the various control circuits; and (2) a main control contact device which only allows a current to be sent into the control circuits when the distributer has selected the circuit which it is desired to energise.

"In order to accomplish this twofold action an electromagnet is provided, through which a current is sent by means of a relay in the

* Extracts taken from a paper read before the Société Internationale des Électriciens, 1906, by permission of the *Electrician*.

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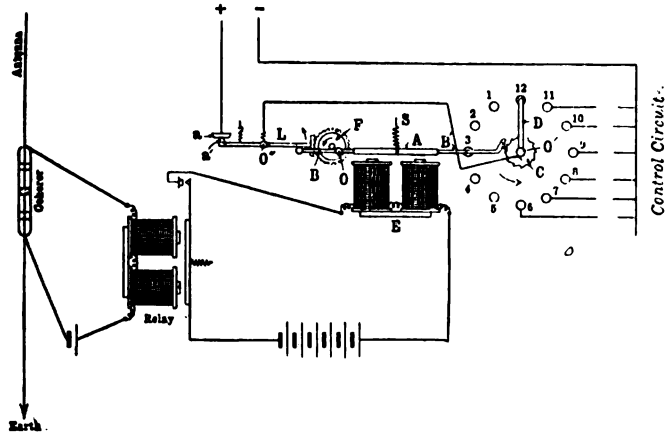

FIG. 91.—*DIAGRAM OF RECEIVING CIRCUIT AS FITTED IN THE CREUSOT BUILT CREWLESS SUBMARINE.*

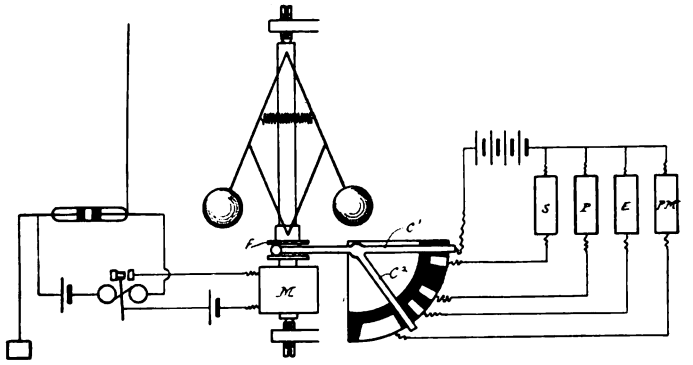

FIG. 92.—*DIAGRAM OF RECEIVING CIRCUIT OF GARDNER'S CREWLESS SUBMARINE, POSITION I.*

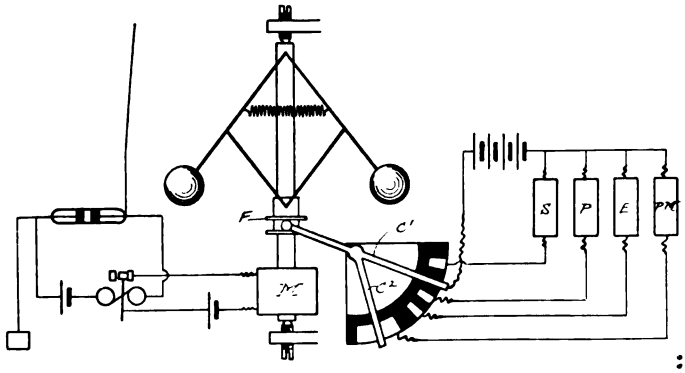

FIG. 93.—*GARDNER'S RECEIVING CIRCUIT, POSITION II.*

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coherer circuit in the usual manner whenever a wave impulse is sent from the transmitting station on shore. This electromagnet acts upon an armature A, normally held away from it by the spring S and carried by a lever BB′, pivoted at O. The lever arm B′ carries a pawl engaging in a ratchet wheel C, which carries the distributer arm D, so that each time the armature is attracted the distributer arm is caused to move one step forward. The other arm B presses against and lifts the lever L pivoted at O″, and causes it to interrupt the main control contact *aa′*. This lever carries at the other end a small rack engaging with teeth on a weighted wheel F. The form of these teeth is such that the rack only engages with the wheel when moving in the downward direction, and the object of the arrangement is to introduce a time lag into the return motion of the lever L owing to the inertia of the weighted wheel F, which has to be started into motion whenever the lever descends. This device prevents the contact *aa′* closing while the rapidly succeeding impulses are carrying the distributer from point to point, and only allows it to complete the circuit when the distributer contact arm has reached its desired position and come to rest. Thus, in order to energise any particular control circuit, or to return the distributer to the "off" position, all that is necessary is to send the requisite number of wave impulses in rapid succession and then pause.

"In the actual submarine with which trials have recently been made, the control circuits actuated relay switches which effected the following actions: (1) Starting of propelling motor in forward direction, (2) starting propelling motor in reverse direction, (3) stopping of propelling motor, (4) movement of rudder to starboard, (5) movement of rudder to port, (6) stopping of steering motor, (7) lighting up of forward signal lamp, (8) lighting up of after signal lamp, (9) discharge of the torpedo. The distributer had in all twelve positions; the three remaining points were "off" positions, and in order to avoid always having to traverse the entire circle, these were spaced at equal intervals. A complete revolution of the distributer could be made in two seconds.

"Energy was supplied from a battery of Fulmen cells with a capacity of 450 ampère hours and a maximum discharge rate of 100 ampères, but the number of cells is not stated. The capacity of the battery is sufficient to run the apparatus for about four hours.

"The shore transmitting station was provided with an antenna

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15 metres high, composed of a group of fine wires, and satisfactory evolutions were conducted over a distance of three miles, in spite of attempts to interfere made by a transmitting station in the vicinity of the roadstead. The inventors * claim that the boat is under perfect control in the horizontal and vertical planes, and the arrangements allow of an explosive charge being dropped or a Whitehead torpedo fired when in close proximity to a hostile vessel."

In Germany these controlled boats are receiving considerable attention for purposes of harbour defence; therefore it would not be out of place to give a few details of a clever invention that has received some notice in this country. This is a Hertzian-wave controlled boat (Plate 108), 16 feet in length, weight 25 cwt. The original object of the inventor,† to use his own description, was to produce a weapon for exploding a heavy charge in the neighbourhood of a submarine, and so disable her. The weapon is not intended for use in the open sea, but for harbour defence; the control is intended to be obtained by an operator placed as high as possible up the mast of a ship or on high land. The explosive can be carried under the boat or in its interior, and can be exploded by making an electric contact in the receiving apparatus to close the firing circuit or by direct impact.

The distinguishing features of this system are—(1) That cessation of sparking brings the weapon to rest, so that if it gets beyond range, or if anything goes wrong, it comes to a stand. The governor is all the time trying to close, and thus to stop all operations. (2) That the various circuits cannot be instantly acted upon, as by interference. To bring about the expansion of the governor under the action of centrifugal force, a great variation in speed of rotation is necessary. The greater the expansion, the greater the power to drive the governor, until the last or exploding circuit can only be closed under favourable circumstances of syntony, power, etc. This stability of the contacts is so great that, without syntony, a message of greater power can be transmitted from the same aerial while the boat control remains unimpaired.

By the abandonment of the usual step-by-step motion it has

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* MM. Lalaude and Devaux.

† From information kindly furnished by the inventor, Mr. John Gardner, Knott End, Fleetwood.

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PLATE 108.—*MR. GARDNER'S CREWLESS SUBMARINE CONTROLLED BY HERTZIAN WAVES.*

On Inventor's left is a Ventilator for carrying off battery gases when charging the Electric Accumu'ators.
The Staff for supporting the Aerial Wire fits into a Socket shown on fore side of Ventilator.

A human being is reading this on November 6, 1989

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been possible to include an exploding contact. Fig. 93 shows the position of the contacts with the boat on a straight course. The upper or steering contact can be moved either up or down for steering purposes an indefinite number of times before closing the last or firing circuit. It amounts to a step-by-step motion, movable either backward or forward. Without the actual apparatus at hand the method of control is difficult to explain, because the mechanical resistance to rotation of the governor designedly increases with its expansion to protect the last or firing contact, and partly because it is assumed at the outset that interference will maintain the governor in continuous rotation, but not at an effective speed. With the boat always in sight the inventor can judge the amount of interference reaching it, and effectually control it by adding transmitting power to the interference. With no transmission there is no operation in the boat, consequently she might lie in wait in a convenient position ready to start. The contacts are never stationary; in Fig. 93 they are slowly moving up and down in correspondence with the time of transmission and the time of rest that follows, but the net effect is fixity, as when a torpedo oscillates under the action of the gyroscope without actually altering the direction.

Fig. 92 is a diagram of the apparatus at rest. Fig. 93 shows the position of contacts controlling the vessel with the rudder amidships and propeller running; to the left of each figure is an ordinary ether wave receiver of any pattern, adapted to the closing of a local circuit in which a motor M is placed. The function of M is to rotate the centrifugal governor, expansion of which causes the muff F to slide on the governor spindle. The vertical movements of F bring about the changes in position of the moving contacts C^1 C^2 over the fixed contacts corresponding to the apparatus to be governed, S, P, E, P M, representing respectively starboard, port, exploding and propeller driving motor. Transmission causes C^1 and C^2 to advance downwards, as in diagrams, while cessation of sparking allows them to return. Equal times of make-and-break at sending station will, apart from considerations elsewhere referred to, cause the contacts to remain in a virtually fixed position.

On seeing a photograph of this boat the author asked the inventor if he had experienced any difficulties with the gases when charging or after charging the electric storage battery. The question elicited

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the following interesting occurrence. "An explosion I had with the boat on the beach was apparently caused by the affinity of hydrogen for chlorine, and the significant part is the certainty that there was no spark in the boat to fire it. The after-cover, having about 2 square ft. area, was removed during charging. The accident occurred at six p.m., boat lying on beach east and west. As the sun set to the westward, rays of sunlight passed through the opening straight into the interior of the boat. The battery was of 150 ampère-hours capacity and 52 volts. Charging had ceased about half an hour before the explosion." In further explanation of this mishap the inventor quoted Tyndall's well-known experiment, taken from his book on sound, which runs thus: "By directing the beam of an electric lamp on glass bulbs filled with a mixture of equal volumes of chlorine and hydrogen, I have caused the bulbs to explode in vacuo and in air." Would not this explanation account for some of the minor explosions that have occurred in the early boats during experimental work, which never could be accounted for as nobody was ever present to cause a spark by the manipulation of an electric switch. If complete interference from hostile transmitting stations can be obliterated, these crewless submarines may have some future before them as an economical form of harbour defence, and are certainly a considerable advance on the old Brennan torpedo with its limited range and cumbersome method of control by wires.

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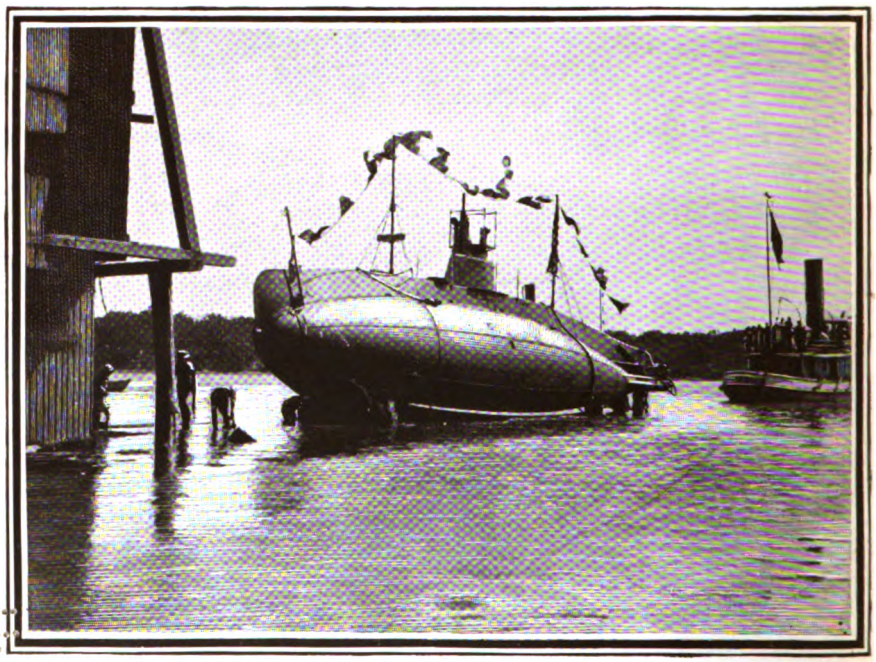

PLATE 109.—*LAUNCH OF UNITED STATES SUBMARINE "CUTTLEFISH."*

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CHAPTER XXVI.

CONCLUSION.

WITH the march of progress steadily onwards, inventions that appear miracles to-day are the ordinary commonplaces of to-morrow. In the evolution of under-water vessels an exceedingly important turn has now been reached; in fact, it may be said we are just entering into a programme of submarine-boat construction that is inevitable.

From the first description of an invention relative to sub-aqueous vessels made by William Bourne towards the end of the sixteenth century down to the launch of the United States submarine "Cuttle-fish" * (Plate 109), a rugged path has been travelled, strewn with many great obstacles. Nature's laws, step by step, have been sub-ordinated to man's inventive genius. In this evolution, and in perfecting the weapons that are used in torpedo warfare, many brave lives have from time to time been sacrificed. In spite of this, the reader will have noticed, during the perusal of the foregoing chapters, the steady advance made by most nations in developing submarine boats. A reflection on this progress will no doubt cause him to agree with the author that we are simply being forced into the construction of this type of war-vessel. The inertness of 1902 and the fallacy of the Arnold-Forster argument, "that submarines are the weapons of the weaker power," has now been fully recognised by the authorities in this country. We cannot afford to voluntarily surrender a weapon of such potency or halt in its development, but must look in other directions to make the work in these craft less hazardous.

The new regulations in regard to this branch of the naval service show that the Admiralty fully recognise the importance of obtaining skilled specialists; therefore future officers and men are to be carefully selected when young, and thoroughly trained in submarine boats.

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* 1907.

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When engaged in those duties they will receive high rates of pay, and no doubt a continuation at this work will lead to early promotion.

Some of the best nerve and intelligence obtainable is required for building up our flotillas of under-water boats (Plate 110). We may even say that the responsibility young officers have thrust upon them in this work will develop their individuality to a far higher degree than in almost any other branch of the naval service, certainly to a point unattainable by years of watch-keeping and following in the wake of the next ahead, as in squadron cruising. Sub-aqueous work demands prompt decision, with considerable self-reliance, in those unforeseen occurrences that are bound from time to time to arise. On the whole, the duties in submarines are more arduous and impose a greater strain on the officers than in any other branch of the naval service.

In making men masters of the emergency nothing can compare to this training.* The knowledge gained by the juggling with buoyancy in experimental work and when manœuvring in these boats is of the highest value and might be the very means, when a crucial test came, of enabling a trained submarine captain to take his surface vessel where others might hesitate.

What the submarine service chiefly requires is men who possess sufficient fortitude to minimise dangers, and who are willing to risk their lives in a simple devotion to duty. This willingness is the very life of our latest branch of the navy; and whilst we can find officers and men to volunteer for under-water work, the nation can confidently assume that the personnel now available in this country for modern naval requirements has in no way deteriorated since the days of sailing-ships—a time when our officers and men ran so many risks from accidents aloft. An efficient captain of a submarine boat cannot be trained in a day; it is essentially a matter of time; and the more the principles and possibilities of submarine boats are studied in peace-time the better will officers, when in command of these vessels in

* In connection with this subject it is not out of place to recall the gallantry of a submarine-trained officer, Sub-lieutenant Roux, who escaped the first explosion when the magazines of the French battleship "Iéna" blew up at Toulon, March 12, 1907. He rallied half a dozen volunteers, got ashore, and attempted to work the valves to flood the dry dock when a shell killed this brave officer in his heroic attempt to save his comrades.

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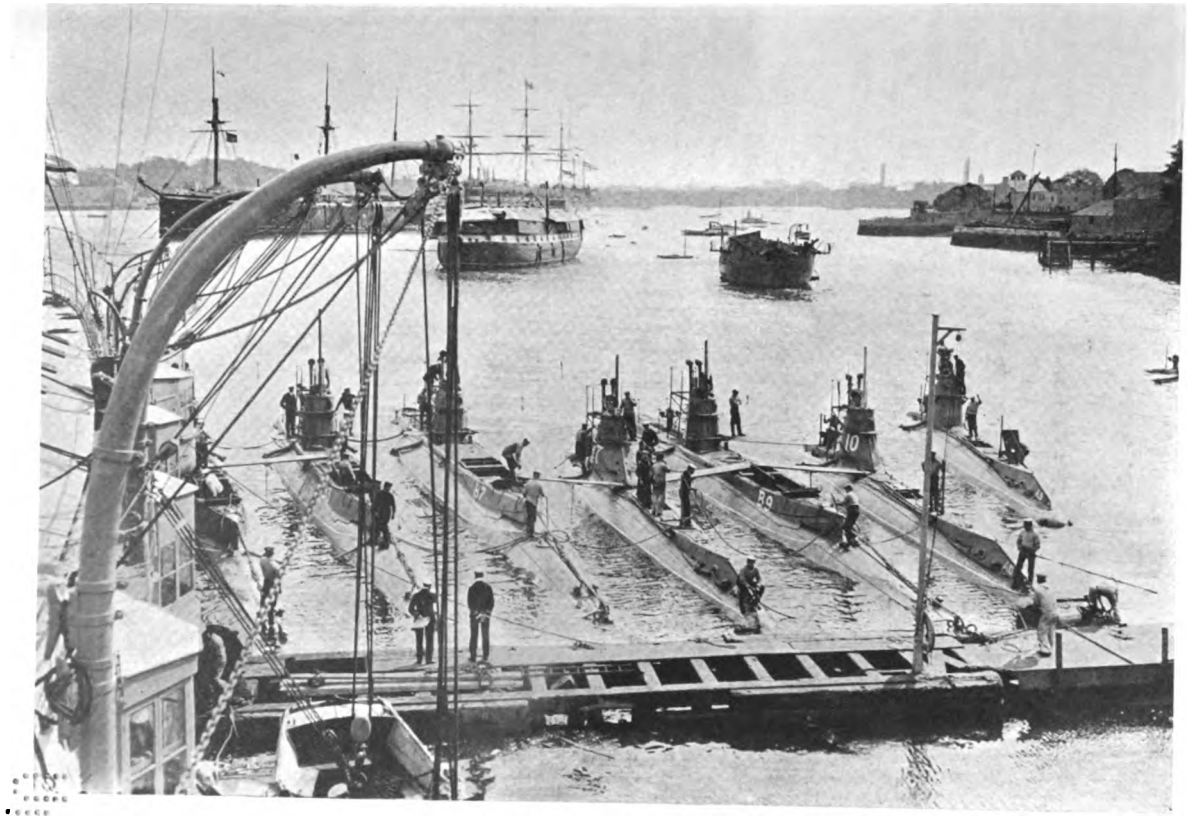

PLATE 110.—*A SUBMARINE FLOTILLA IN HARBOUR.*

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war-time, be able to cope with any duty they may be called upon to perform. The submarine flotillas, if used as a school of training for a portion of the destroyer captains, would instil into them an accurate knowledge of the capabilities of under-surface vessels and so lay the foundation for good ideas in attacking and attempting to minimise the offensive power of hostile submarines. Up to the present the destroyer is the only weapon we have for meeting the submarine menace of other nations.

Another important feature is the feeling of *camaraderie* between the officers and men. This is good for the service. Both take the same risks, and the men have the fullest confidence in their officers. A smartly worked submarine boat, with crew stationed at kingston valves, electric switches, diving rudders, etc., is as pleasing a sight as we have in our navy to-day. It cannot be emphasised too strongly that the most important feature of all torpedo warfare is the training of the personnel; and when once trained, adequate supervision of the work entrusted to each individual is absolutely imperative to ensure success; without this torpedo warfare should never be attempted. The accident to the Russian mine-layer "Yenesei," * the failure of the Russian destroyers to appreciate their proper function, and the limited success compared to opportunity of the Japanese torpedo craft during the late war clearly emphasises this necessity. However good the material may be, it is useless unless the personnel has been trained to a very high standard of efficiency. This points to the grave responsibility resting on the shoulders of those who are in any way connected with this important duty.

The lines of training should never be permitted to run for long periods in fixed grooves; but the effects of new weapons in their relationship to old must be closely studied, so that the personnel may be instructed to learn and appreciate the weapons of the near future more than those of the past. Enquiries into the relative value of submarine boats, modern locomotive torpedoes, offensive mines, etc., must not be delayed to the hour of war; but it is necessary to watch carefully the development of these weapons day by day and embody their teachings in all details of training, future warship design, and future strategy. We may say that maritime warfare, without losing its essential nature, which demands an intimate

* See page 282.

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knowledge of the sea, a high degree of fearlessness and promptness in assuming the offensive, is becoming more and more a matter of specialisation, skill, and efficiency. There can be no impromptu providing torpedoists or their weapons in naval fighting, but each nation must rely on her resources amassed before war, and these resources must be adapted to meet any and every possible emergency. It is the country which courageously uses the most up-to-date scientific torpedo weapons in time of need that makes the greatest stride towards the fulfilment of Fulton's dream that "the liberty of the seas will be the happiness of the earth."

In glancing at the military situation of to-day, that is, some hundred years after Fulton's strenuous endeavours in the direction of annihilating navies by submarine explosives, we notice that the question of the limitation of armaments is occupying the attention of the great Powers; and it is of interest to record that the British Premier, Sir Henry Campbell-Bannerman, speaking at Manchester on May 9, 1907, said: "We still seek to carry out the policy advocated after the Crimean war by Mr. Disraeli when he said, 'Let us terminate this disastrous system of rival expenditure, and mutually agree, without any hypocrisy, but in a manner and under circumstances which can admit of no doubt, to show by a reduction of armaments that peace is really our policy.'" In connection with the same subject the German Chancellor, Prince Bülow, in his speech to the Reichstag the week previous, made it perfectly clear that Germany is strongly opposed to any discussion on limitation of armaments. Also the *Novoe Vremya*, a leading Russian paper, observes, at about the same date: "We are not inclined to confide our faith again to the hands of those friendly advisers to whom we owe the conclusion of the Portsmouth treaty of 1905."

As these opinions have been thrown broadcast to the world on the eve of the second Hague Conference, we may assume that for some time to come no great progress will be made in the direction of reduced armaments. This country, we constantly read, once emerged from a long series of wars, terminating with Trafalgar at sea and Waterloo on land, with a complete mastery of the sea. No nation was then in a position to contest our naval supremacy. Had we at that time possessed a great statesman to formulate a policy for the restriction of armaments, much of the excessive taxation now being levied on the people of the most

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important nations would have been rendered unnecessary. However, this grand opportunity was lost; and before Fulton's ideal can be realised many changes in the countries of the world will undoubtedly take place, in the accomplishment of which the several weapons that can be used in torpedo warfare will play a not unimportant part. The recent improvements made in one of these weapons—the Whitehead torpedo—enhances the value of the submarine boat, and, by the development of this type of vessel, war will be made more deadly than hitherto.

Future progress indicates that most maritime nations are developing the large submersible class, that is, those vessels with a reserve of buoyancy on the surface of 25 to 30 per cent. of their total displacement, in preference to the submarine proper, with only a reserve of buoyancy of from 5 to 10 per cent. of the total displacement. The United States is keeping more to boats of the diving type with no large amount of reserve buoyancy on the surface, but has added hydro-planes to her new designs.

In this country our submarines are now more nearly approaching the submersible type, that is, the small reserve of buoyancy noticeable in the surface-trimmed condition of the "A" class has been largely increased in the recent designs; also hydro-planes have been added to enable the boats to go under water on more of an even keel than hitherto, and this allows of an increase in longitudinal stability.

Further developments in ballast control are necessary to bring the boats quickly from surface trim to that condition in which the horizontal rudders, assisted by the hydro-planes, can overcome the reserve of buoyancy.

Speed in handling large volumes of water will in time be better understood, and no doubt more powerful pumps may become available without any large increase in weight—the great bugbear of submarine designers. In peace-time there is no necessity for running on the surface with any water-ballast-tanks full, but in war-time there is no reason why, with ordinary care, some of the ballast tanks should not be kept partially filled. This would then considerably reduce the time for disappearing. Improvements in this direction are taking place, as the French submersible "Narval" took 20 minutes to disappear from surface trim, whereas the submersible "Aigrette" can do it in 4 minutes 30 seconds. The "Fulton" takes 11 minutes 50 seconds, the latest "Lake" boats under 10 minutes, and in the

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contract for the United States submarine "Octopus" the time laid down for disappearing from the surface condition is 8 minutes.

The author begs to thank his readers for following him through the evolution of the chief weapons used in under-water attacks, and invites them to pay a last tribute to the brave and skilful pioneers in hoping that their heroic efforts and sacrifices may be a great example to us all, whether our duty lies on or under the surface of the water. To experts submarine work offers no great difficulty, but in training, or when carrying out experiments, dangers may from time to time arise. Hasty criticisms of mishaps are very much to be deprecated, as it is only due to those officers and men who voluntarily give their services in working out new ideas for the benefit of their country that judgment should be suspended until all the facts of the case are known. If their lives sometimes pay the price for this devotion to duty, as was the case in the lamentable accident to "A 1" submarine, surely blame must not be attributed without direct evidence of some neglect on the part of one or more of the crew. The sad accidents that have since happened in the British Navy have in no way deterred officers and men in volunteering for this new branch of the service. They well know that the Admiralty, and those in whose hands the construction of our submarine boats is placed, are doing their utmost to minimise any risk that service in these craft may entail. Human errors, we all recognise, cannot be entirely eliminated; but by a better appreciation of the conditions of equilibrium, buoyancy, and fuel dangers, consequent on constant practice, mishaps in the future should be gradually reduced to a minimum. That submarines and their weapons will form the chief protection of our coast-lines and adjacent narrow waters in our next naval struggle, there can be no reason to doubt. On the energy, skill, forethought, and patriotism of the personnel engaged in this branch of torpedo warfare, much will depend and great deeds may be accomplished.

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AUTHOR'S NOTE.

THE Author, in seeking information from the sources named, and many others, fears that he has paid insufficient acknowledgment for the extracts taken. A good many early quotations have been made, as they are more interesting than if the writer had paraphrased the descriptive matter and then referred to the passages incidentally. In a work of this kind a naval officer is handicapped by having no library of reference that he can have ready access to; a small cabin containing a few works connected with the subject is all that is available; and rarely, during a busy life, can he afford an afternoon at the British Museum, even when stationed in home waters. For instance, the figures given in the chapter on French submarines have been compared in all the different foreign books obtainable on the subject, and are fairly accurate for purposes of comparison, but are by no means to be regarded as strictly correct.

If any readers would be so kind as to point out any errors, these would be gratefully acknowledged and corrected on the first available opportunity.

In acknowledging the photographs and drawings named in the list of plates, the Author wishes to thank those officers and others for their very kind assistance in helping to make his book on submarine boats of greater interest.

H.M.S. "BARHAM,"
MEDITERRANEAN SQUADRON,
June 10, 1907.

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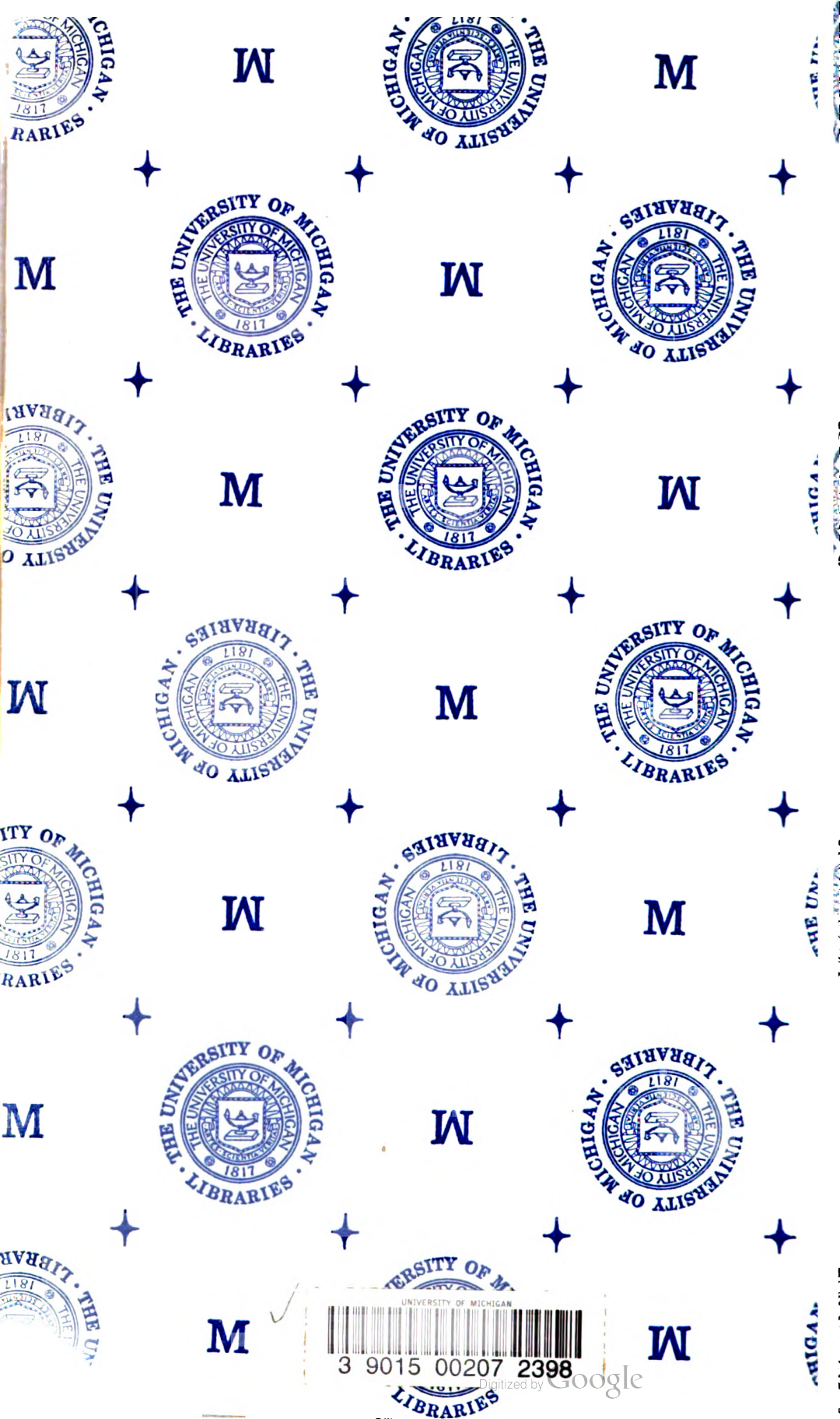

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